Advanced Core Data Usages

Session 143

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Application Technologies

Advanced Core Data Usages

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http://developer.apple.com/wwdc2005/

Core Data Review

- Core Data is a model-driven object graph management and persistency framework
- Provides
  - Scalable object life cycle management
  - Automatic undo/redo support
  - User interface synchronization through Cocoa bindings integration
  - Data consistency and correctness
  - Reading/writing to various types of files

Core Data Benefits

- Relieves you from having to reinvent the wheel
- Faster development cycle
- Likely more robust applications
- Prepares your application for future features in Cocoa

What this Session Will Cover

- Architecture:
  The individual components
- The stack:
  Putting it all together
- Advanced topics:
  Working through the tough stuff
- Problems and decisions:
  Things to think about

Core Data Architecture

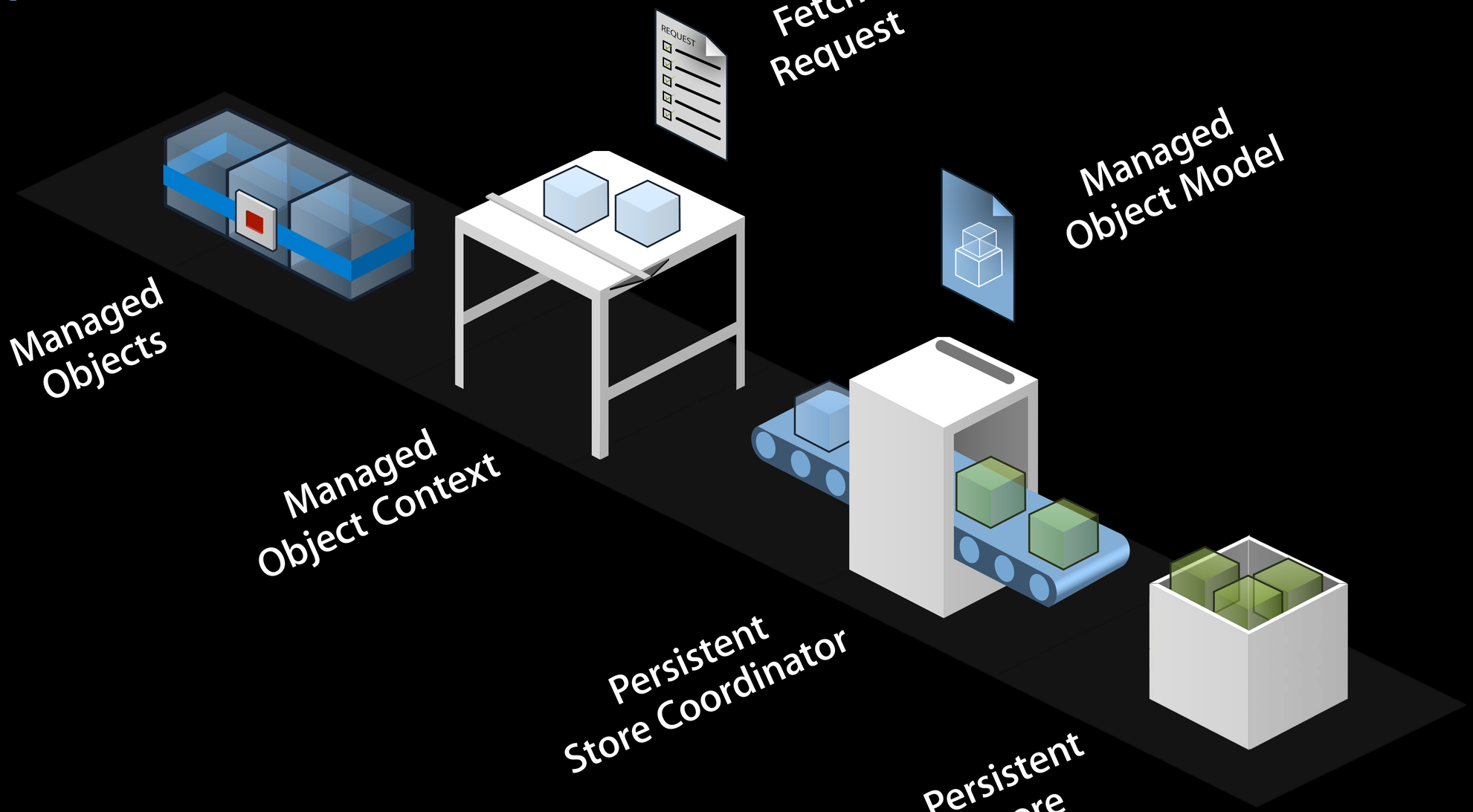
http://developer.apple.com/wwdc2005/

Architecture

- Core Data architecture built from the following
  - Models
  - Managed Objects and Object Context
  - Predicates and Fetch Requests
  - Object Stores and Store Coordinator
- Integration with Cocoa
  - Documents and Controllers
- Design tool in XCode can be used to create models
- XCode includes templates for creating Core Data applications

The Core Data Architecture Slide

The "persistence stack"



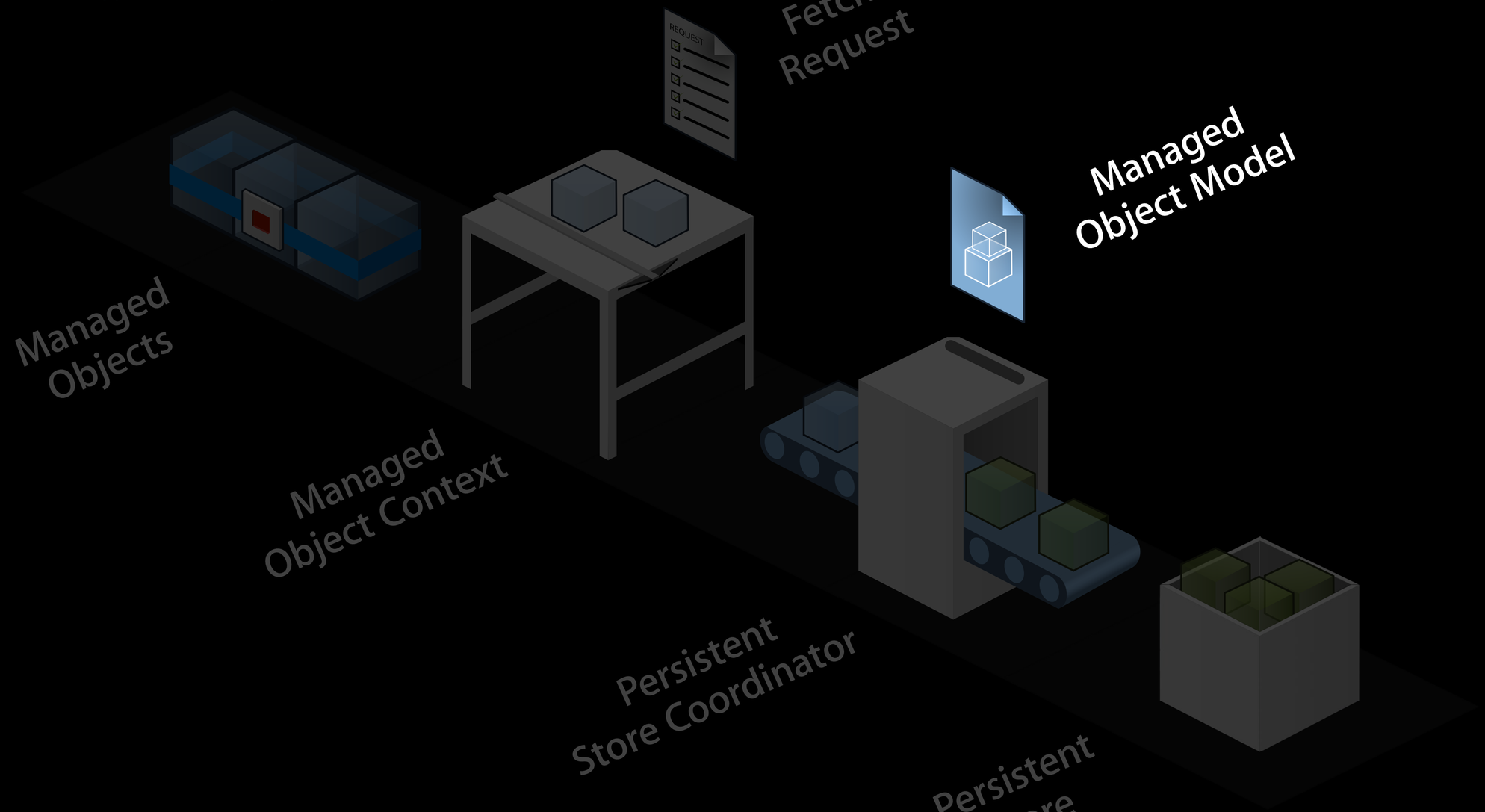
The Managed Object Model

NSManagedObjectModel

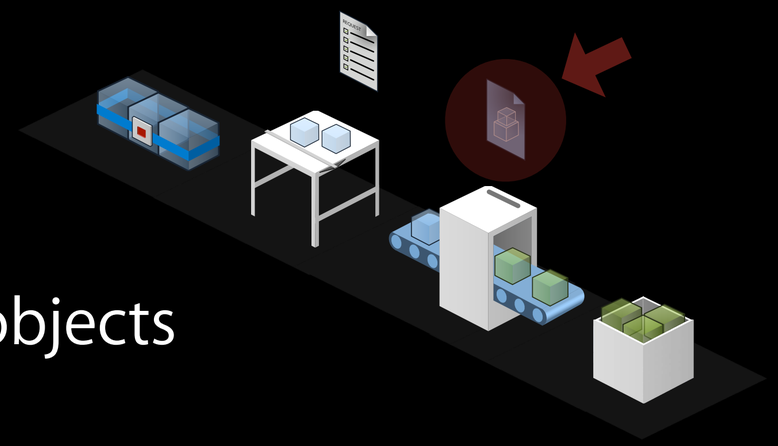
http://developer.apple.com/wwdc2005/

Core Data Models

NSManagedObjectModel

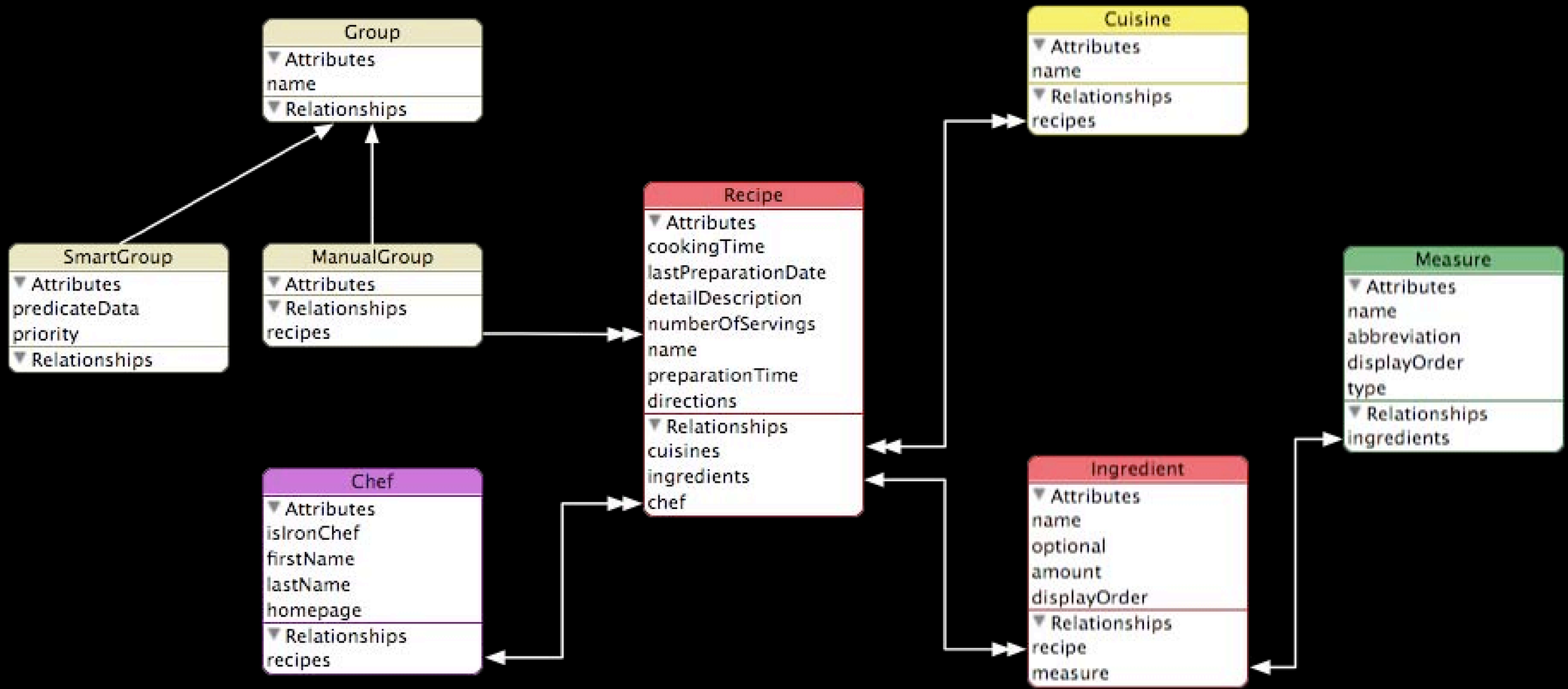


NSManagedObjectModel



- A model is a blueprint
  - Interaction between application data types and objects
  - Focus on architecture rather than flow
  - Baseline for model-based development
- Two main elements
  - Entity descriptions
  - Configurations

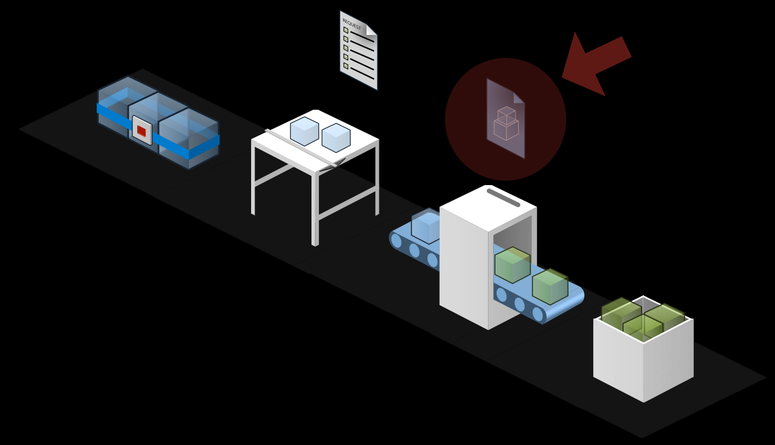
The Core Recipes Model



Anatomy of NSManagedObjectModel

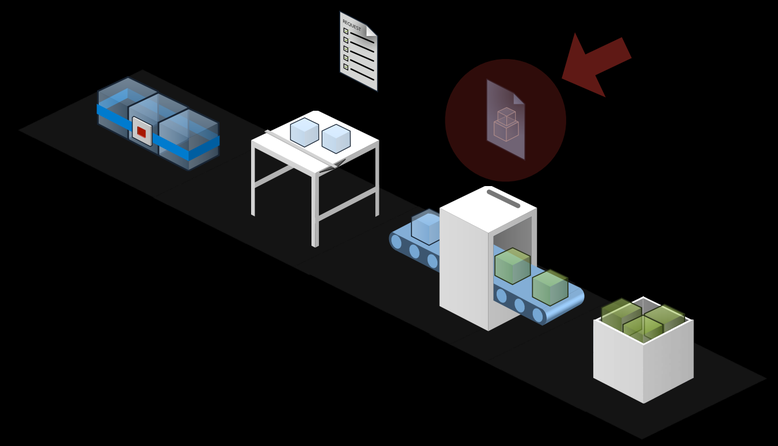
Element	Core Data Class
Entity	NSEntityDescription
Attribute	NSAttributeDescription
Relationship	NSRelationshipDescription
Fetched Property	NSFetchedProperty
Fetch Request Templates	NSFetchRequest
Configurations	n/a

Entities



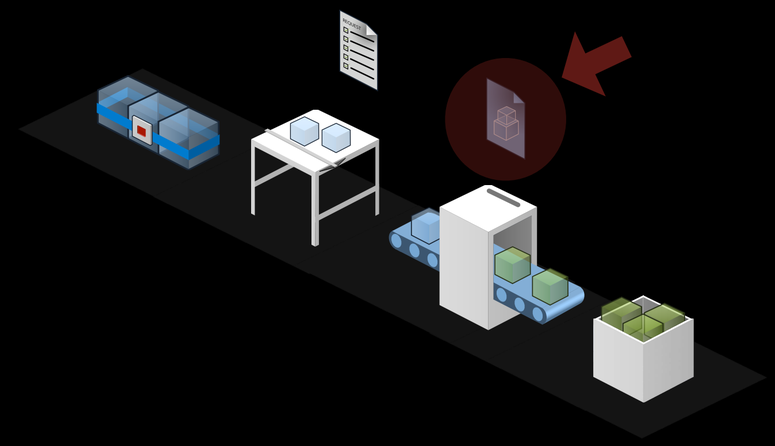
- Named bag containing information about related data
- Several property types
  - Attributes
    - Contain value data
  - Relationships
    - Contain interaction information
  - Fetched properties
    - Allow for weak unidirectional relationships
    - Special predicate variables
    - Only refresh when object is refreshed

Properties



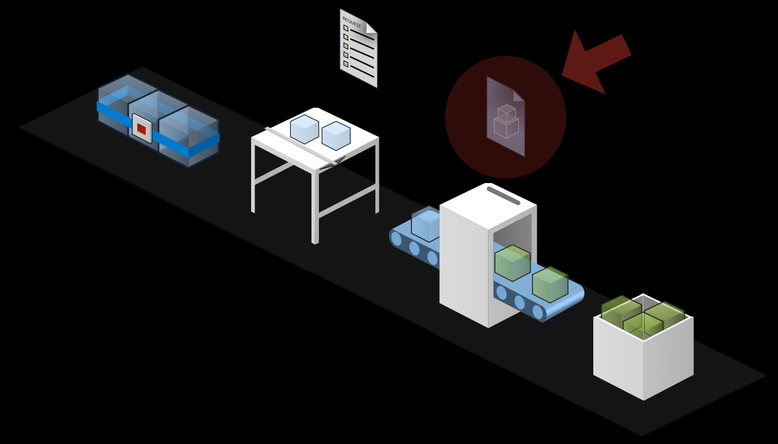
- Data containing elements of an entity
  - Can be transient or persistent
- Transient properties are used to
  - Store cached data calculated during application processing
  - Hold unsupported data types
  - Contain cross-store relationship information
  - Store derived properties

Relationships



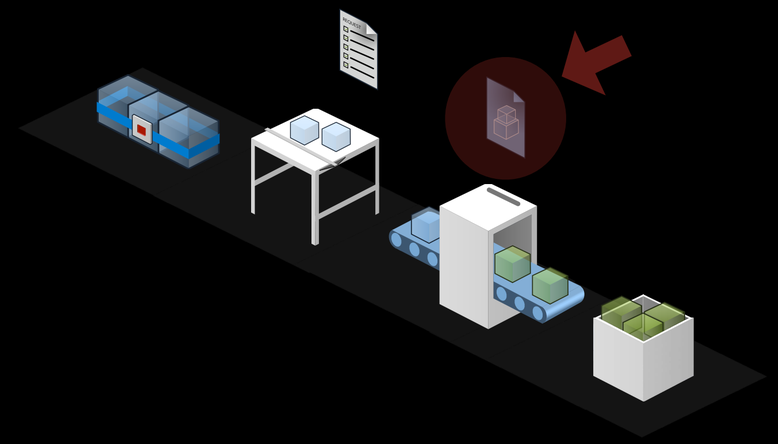
- Relationships are sets, not arrays
  - No ordering
  - Unique correlations
- Core Data manages inverse relationships for you
- Delete rules
  - NSNullifyDeleteRule
  - NSCascadeDeleteRule
  - NSDenyDeleteRule
  - NSNoActionDeleteRule

Relationships Are Not Ordered



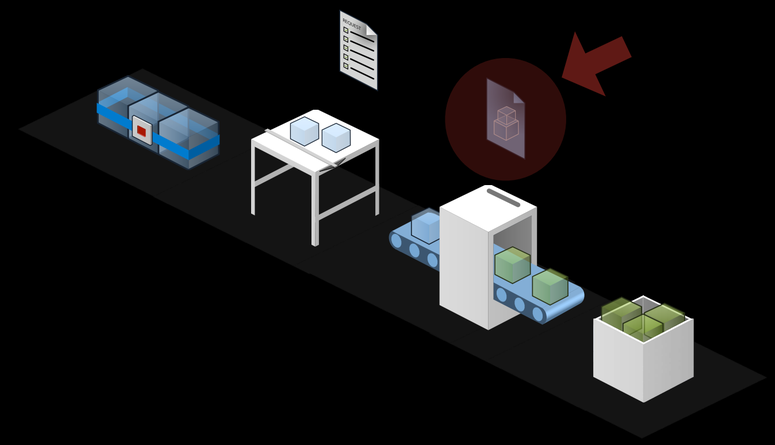
- Most data are not inherently ordered
  - Employees
  - Books
- Some data are ordered
  - Entries in a ledger
- Do you really need order? Or merely the appearance of order?

Problem: Achieving Order



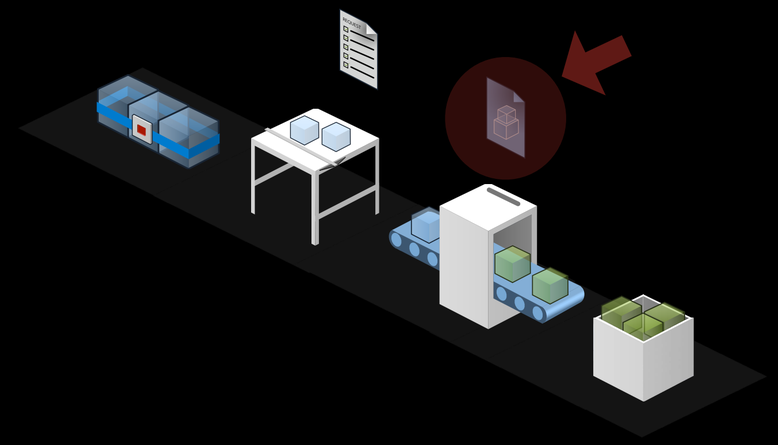
- Appearance of order
  - Use fetch requests with sort orderings
  - Use sort orderings on array controllers
  - Use NSArray's sorting methods
- For real order
  - Create an order column attribute
    - You'll have to maintain this explicitly

Loading Models



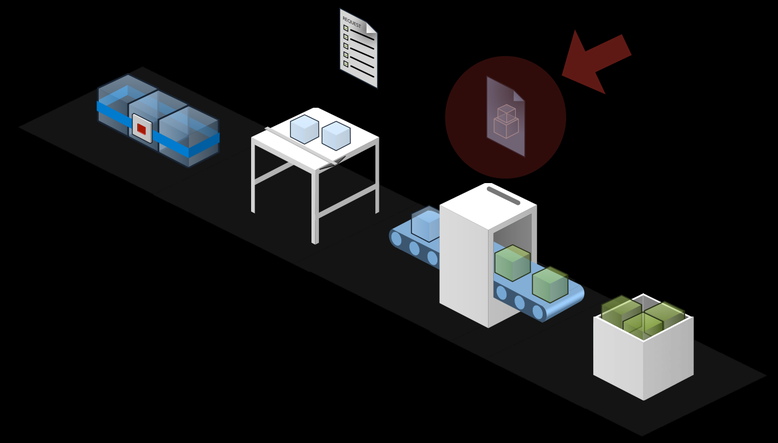
- A single model
  - -initWithContentsOfURL:
- Multiple models from multiple bundles can be merged at runtime
  - +mergedModelFromBundles:
  - +modelByMergingModels:
- No entity overlap
- Configurations will be merged as well

Problem: Good Model Design



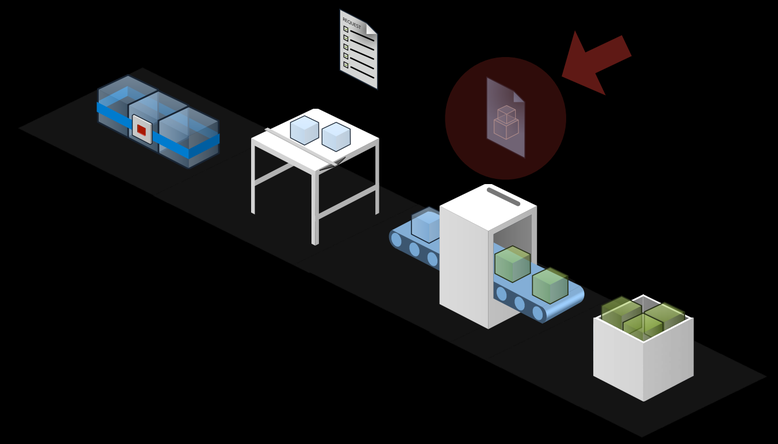
- Put large data objects at the end of one-to-one relationships
- Can’t query NSData attribute types
  - Consider extracting bits you may want to query
- Normalize dataset to avoid duplication or loading more data than necessary
- Caveat: Joins are expensive
  - Consider denormalizing data if frequently used queries will use joins

Problem: Old Data, New Model

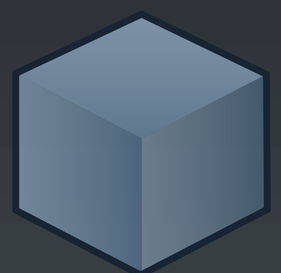


- Applications change over time
- Users have old data they want to use
- Generic solution is difficult
  - Entity inheritance
  - Relationships
  - Dependent properties
- How to upgrade stores
  - Create two stacks, one with each model
  - Load objects from old store; copy data into new objects in new store

Store Upgrade Tips and Tricks



- Multiple passes over data
  - Move discrete, separable chunks independently
  - Minimize memory use
- Models can be modified at runtime
  - Temporary disabling of validation requirements
  - Use NSManagedObject instead of custom classes
- See upgrade example on WWDC source CD



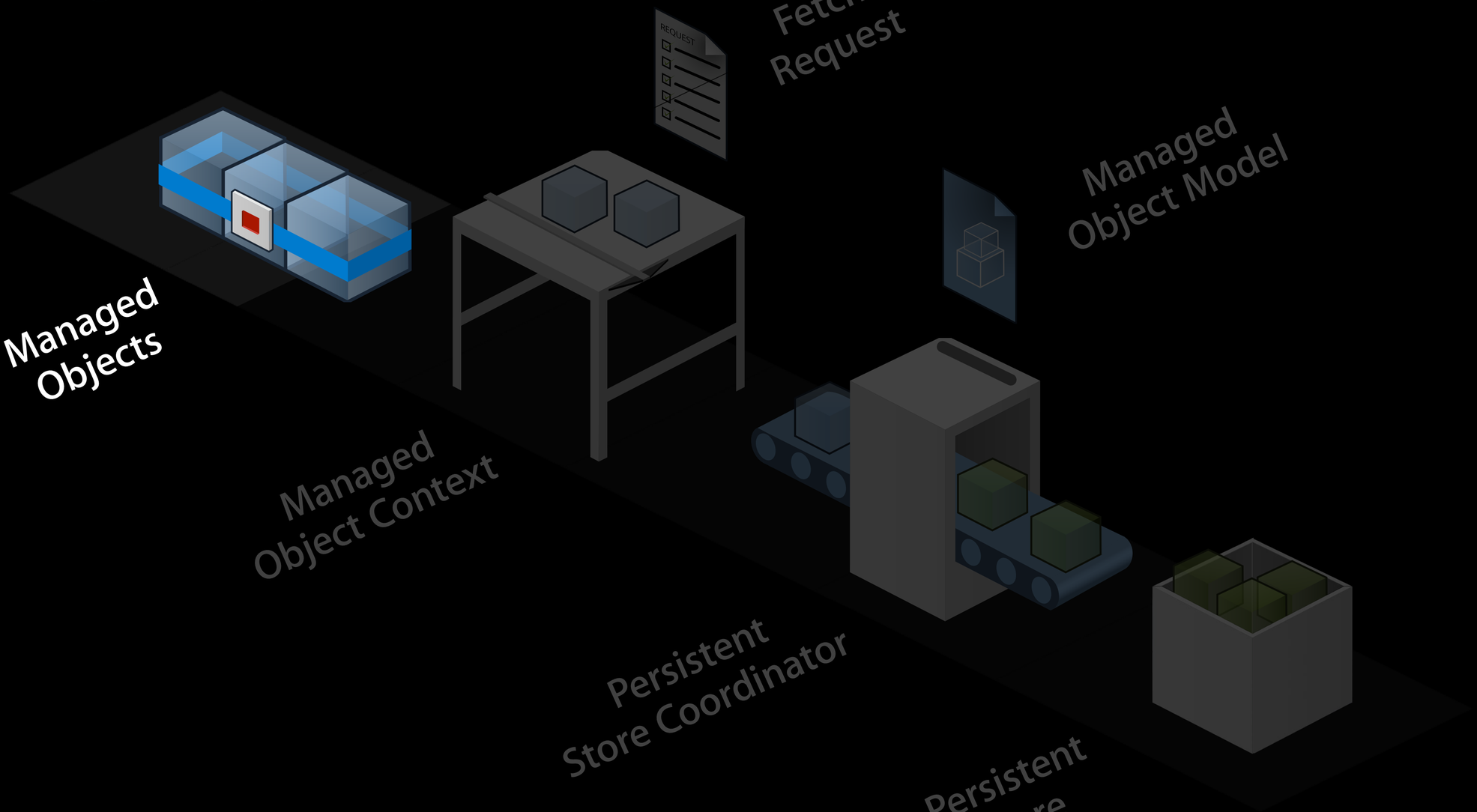
The Managed Object

NSManagedObject

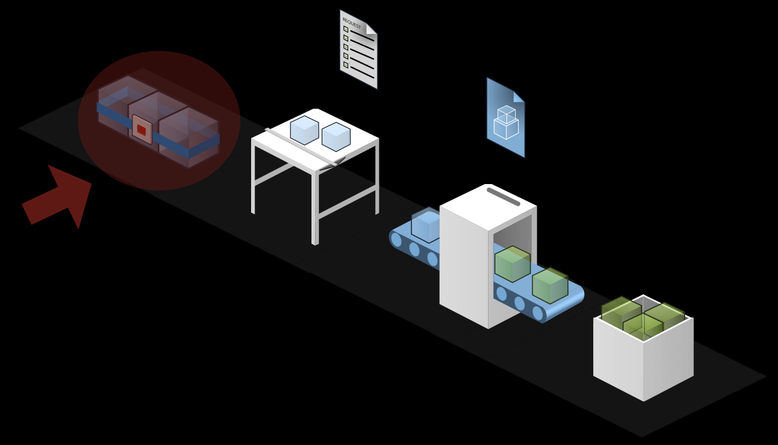
http://developer.apple.com/wwdc2005/

Core Data: Managed Objects

NSManagedObject

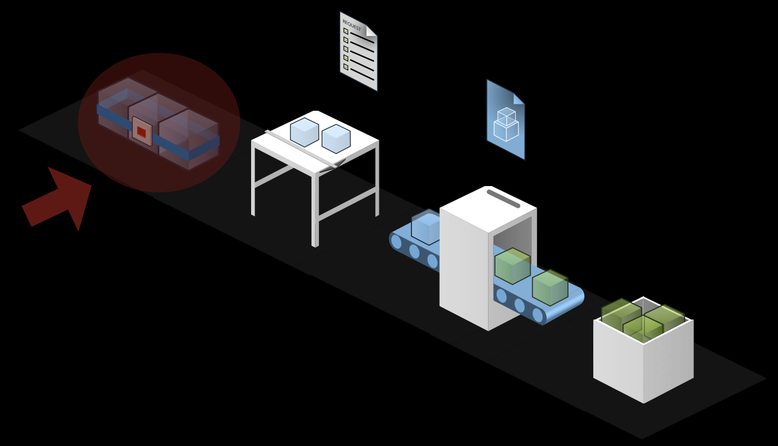


Managed Objects



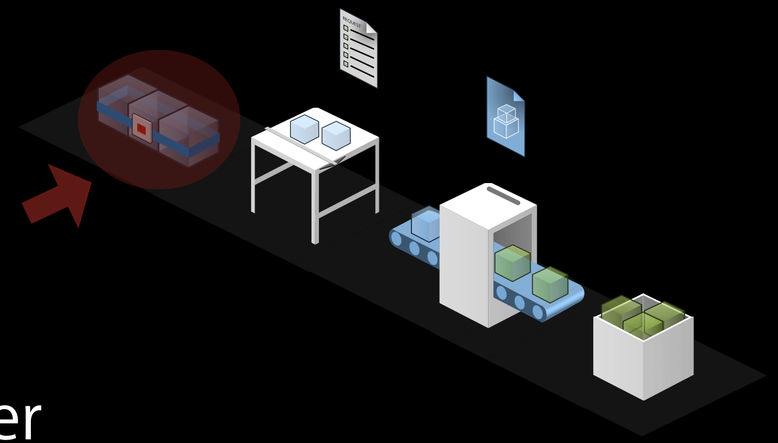
- NSManagedObject is the root class for Core Data
- Managed Objects are to Entity as instances are to Class
- Basic unit for development and operations
  - Fetch, insert, update, delete, save
  - Analogous to a database row or XML node
- Core Data noun

Managed Objects



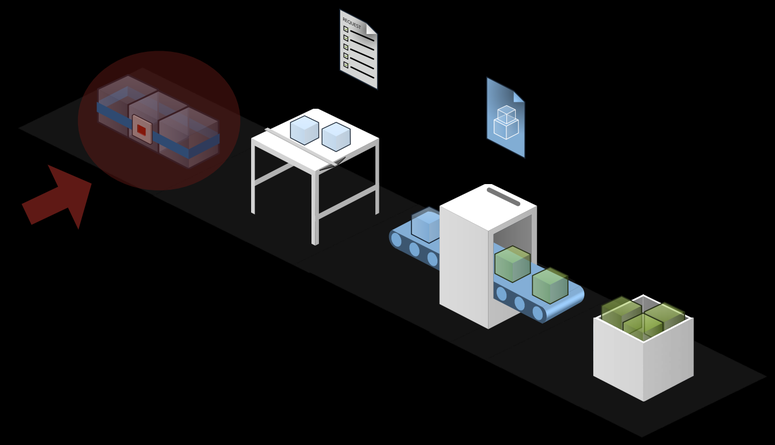
- Each Managed Object
  - Described by a single entity
  - Possesses unique NSManagedObjectID
  - Associated with one NSManagedObjectContext
- Subclasses can implement
  - Custom logic
  - Framework callbacks
  - Validation
- Conforms to NSKeyValueCoding
- Conforms to NSKeyValueObserving

Lifecycle of a Managed Object



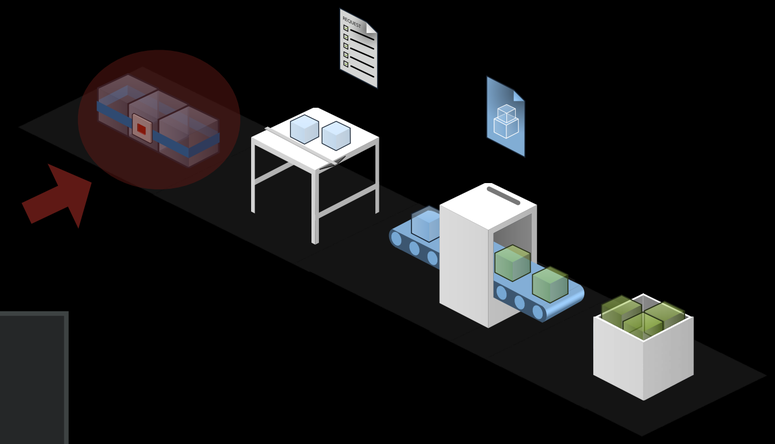
- Normal object lifecycle
  - alloc/init/retain/release/dealloc
  - Once an object is deallocated, it's data is no longer accessible
- Persistent object lifecycle
  - initWithEntity:inManagedObjectContext: & save
  - deleteObject: & save
  - retain/release/dealloc works normally for the current working set
  - dealloc does not cause a persistent object to be deleted

KVC/KVO Support



- Core Data provides KVC and KVO over all modeled properties
- mutableSetValueForKey:
- Dependent key notifications
- KVC and setValue:forKey: retains, does not copy
  - Don’t set a property to a mutable object and then mutate that object

Primitive KeyValueCoding

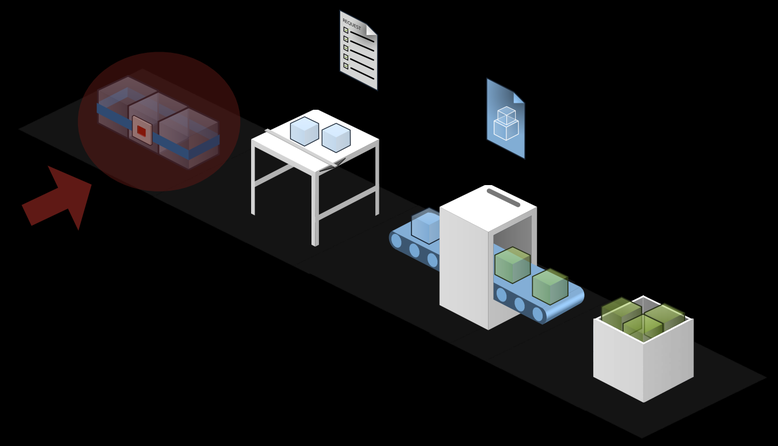


- NSManagedObject provides API:

```
- (id)primitiveValueForKey:(NSString*)key;
- (void)setPrimitiveValue:(id)value forKey:(NSString*)key;
```

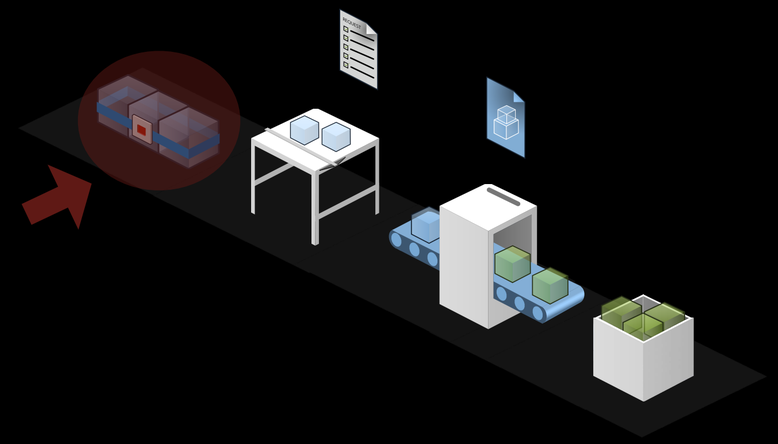
- Does **NOT** go through KVC accessor methods
- Does **NOT** perform validation, argument checking, or relationship integrity management
- **ONLY** for subclasses to implement custom accessor methods
- What does this mean for sets (ie setPrimitiveValueForKey: mySet)

NSManagedObjectID



- Identifies managed objects in contexts or applications
- Managed objects with the same ID refer to the same
  - XML node
  - SQL row
- Managed object IDs can be archived and recreated later
- Offer a URI representation

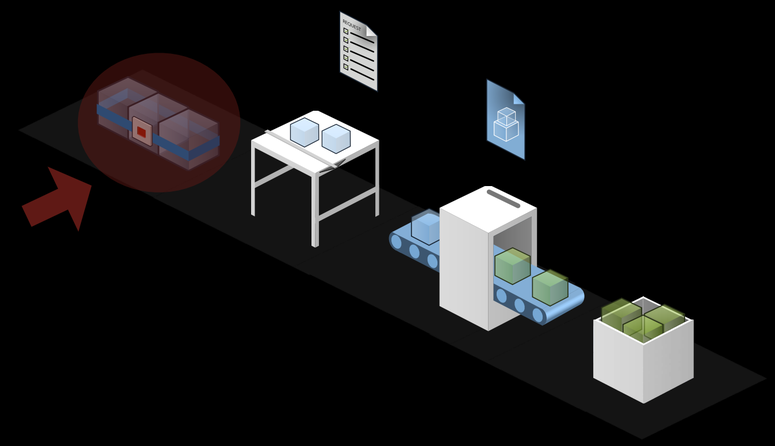
Object IDs



- NSManagedObjectIDs unique to their persistent store
- Customizing the URI scheme
- Passing URIs to other applications
  - objectWithID + executeFetchRequest (self = ID)
  - Issues with temporary IDs
    - Permanent ids assigned during save
- Object IDs can be passed around in a thread safe manner
- IDs change for newly inserted objects and store migrations

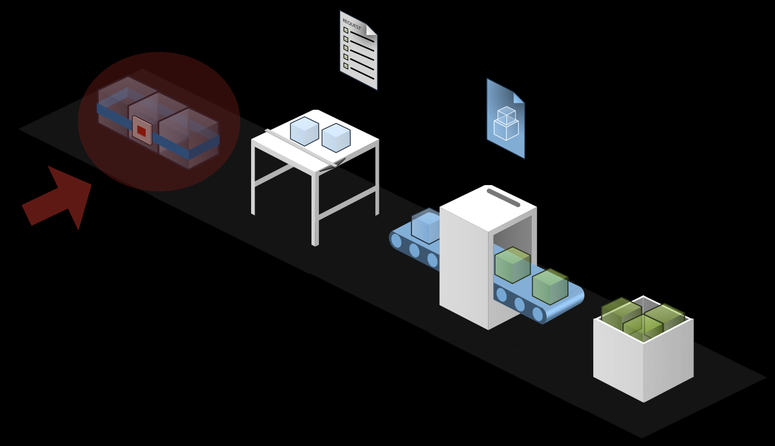
Subclassing NSManagedObject

Subclassing



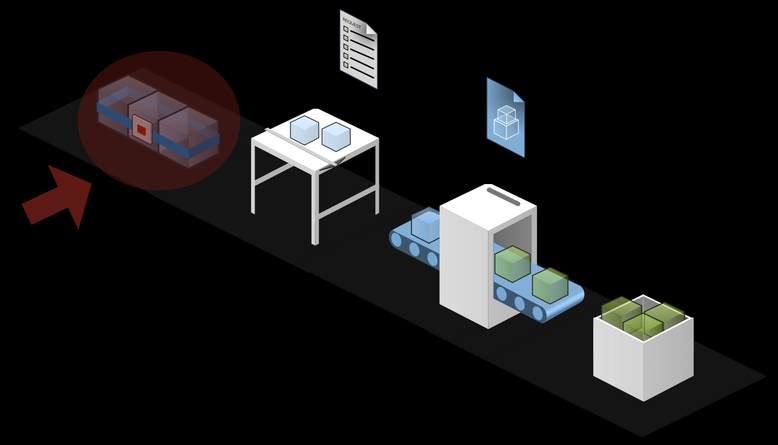
- Life cycle of NSManagedObjects belongs to framework
  - Only need to initialize objects you are inserting
- Don’t use -init
  - Managed Objects without entities are very unhappy
  - Use initWithEntity:insertIntoManagedObjectContext:
- Cleanup in didTurnIntoFault instead of dealloc

Subclassing NSManagedObject



- Callbacks
  - -awakeFromFetch
  - -awakeFromInsert
  - -didTurnIntoFault
  - -willSave
  - -didSave
- Validation callbacks
  - -validationForDelete:
  - -validateForInsert:
  - -validateForUpdate:

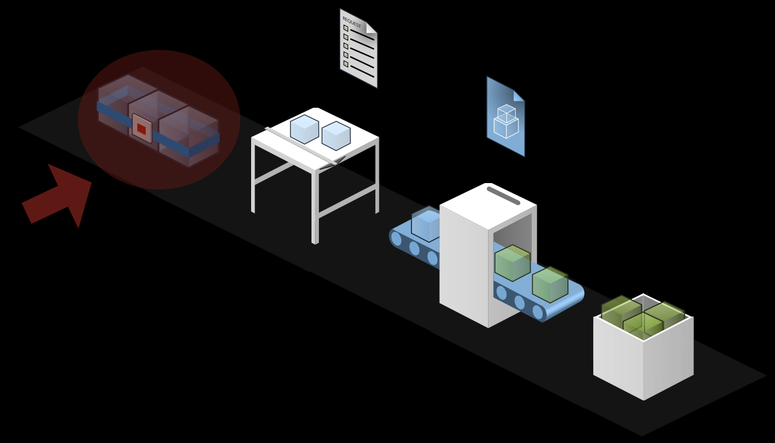
Let Us Manage Space for Properties



- More efficient than defining your own ivars
- Encouraged for attributes
- Mandatory for to-many relationships and fetched properties
- For to-many relationships:
  - Prefer -mutableSetValueForKey: to custom accessor methods
    - Much more efficient

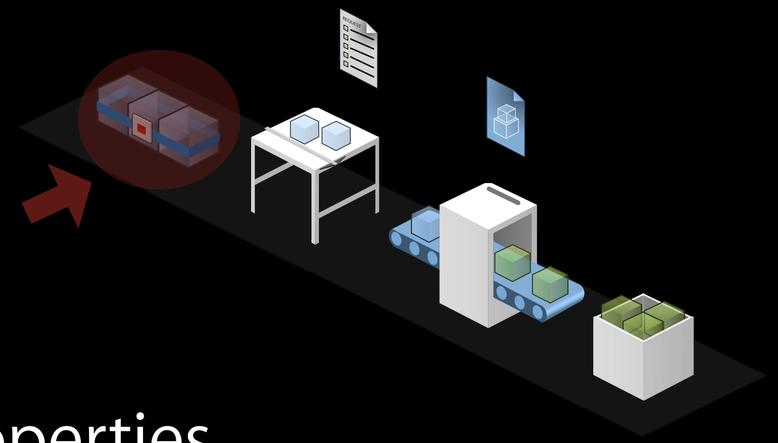
Using ivars for Modeled Attributes

If you must

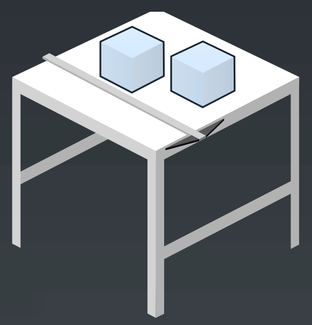


- Attributes should use immutable value classes
  - NSString, not NSMutableString
  - Scalar types supported by KVC are also okay
- Use accessor methods which send KVO notifications

Unmodeled Properties



- Data not described by the Entity
- Usually ivars on your subclass
- Core Data does not interact with unmodeled properties
  - No persistence
  - No undo
- Free form customization
- Maintain in same callbacks as transient properties



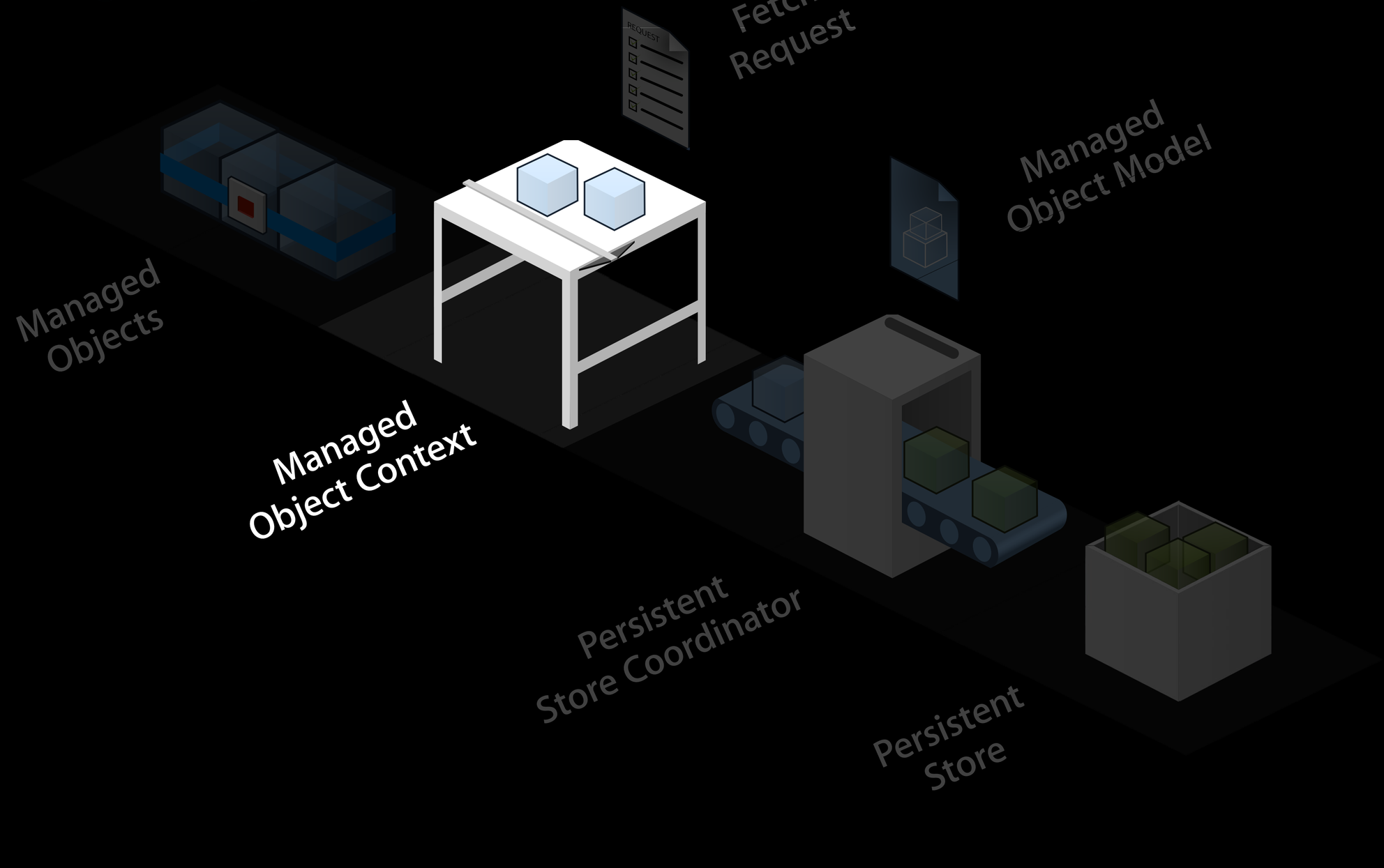
The Managed Object Context

NSManagedObjectContext

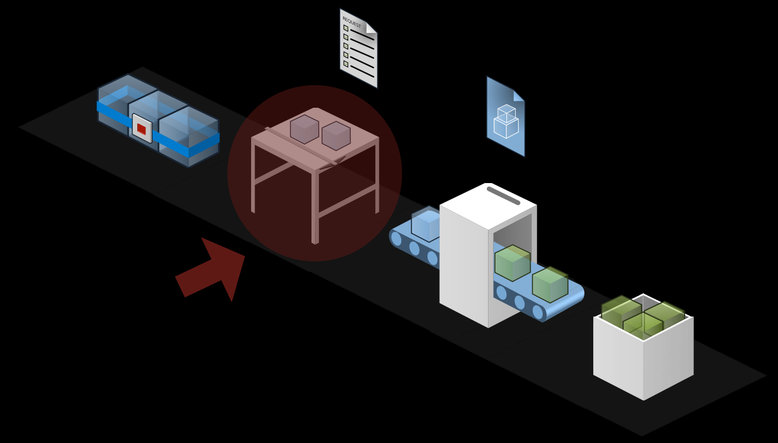
http://developer.apple.com/wwdc2005/

Core Data: Managed Object Context

NSManagedObjectContext

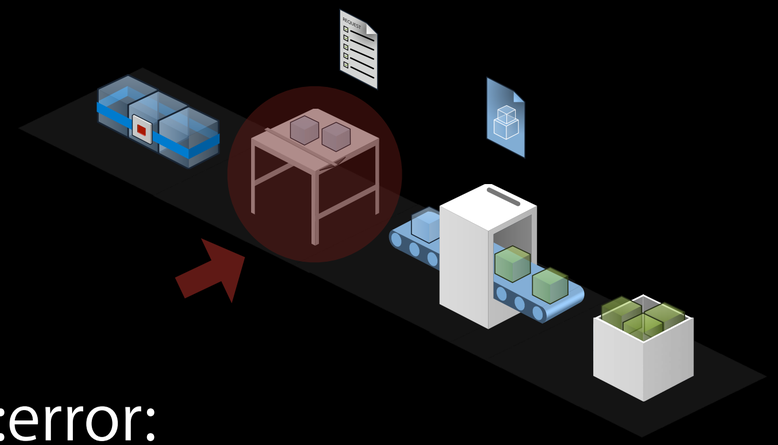


Managed Object Context



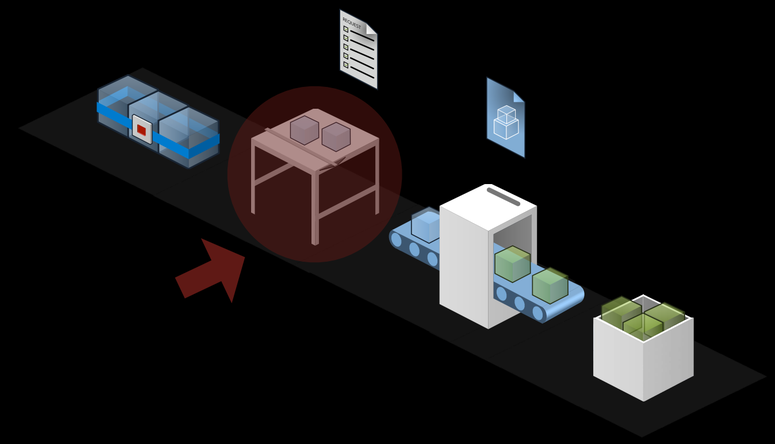
- Working set of Managed Objects
- Scratch pad for changes
- Responsibilities
  - Fetches objects from external store
  - Saves and reverts changes
  - Undo and redo operations
  - Notifications and callbacks
- Core Data verbs

Finding Data



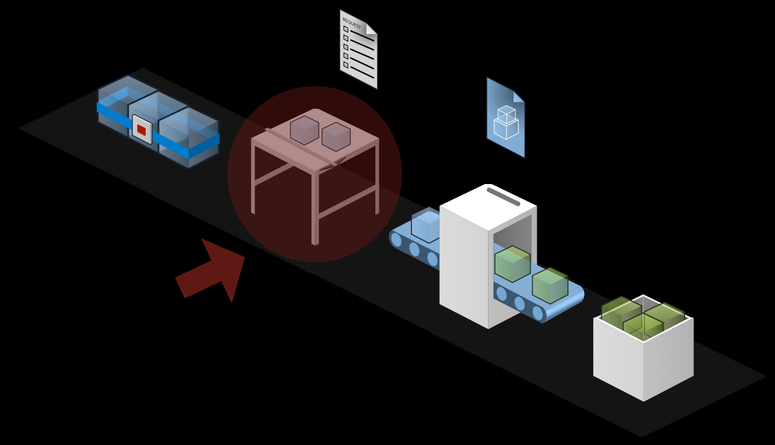
- Fetch requests
  - Entity, Predicate, Sort descriptor
  - Pass request to Context via executeFetchRequest:error:
- By object ID
  - -objectWithID:
    - Always return the object or a proxy for it
  - -objectRegisteredForID:
    - Returns nil if the object has not already been fetched or created

Unsaved Changes Affect Fetching



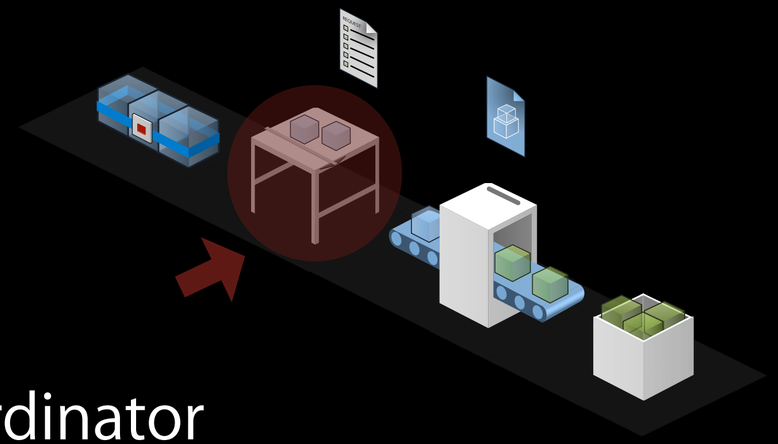
- View of your data incorporating some pending changes
- Fetch results reflect those changes
  - If changed objects match the fetch request's predicate
  - Inserts added
  - Deletions removed
  - Changes merged
- Fetching with lots of unsaved changes slows performance

Deleting an Object from a MOC



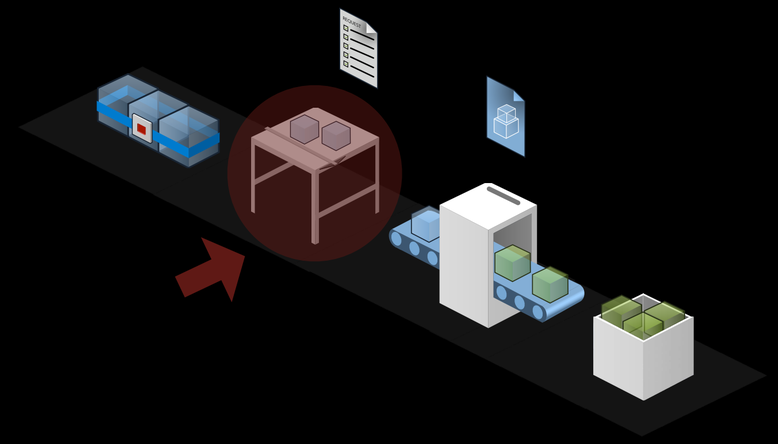
- Send `-deleteObject:` to the context
- Deletes propagate through relationships
  - Propagation is delayed
- Until `-saveChanges:` invoked
  - Changes are coalesced and remain pending
  - Objects are valid and usable
  - Deletion can be undone

Saving Changes in a MOC



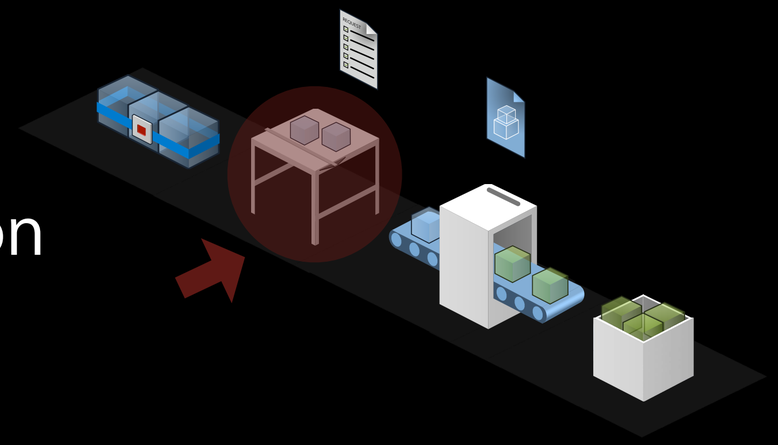
- Managed Object Context
  - Groups all the insertions, deletions, and updates
  - Passes a save request to the Persistent Store Coordinator
- Persistent Store Coordinator
  - Sends changes to the appropriate object store
- Each persistent store
  - Writes out the changes using its native mechanism

Reverting Changes in a MOC



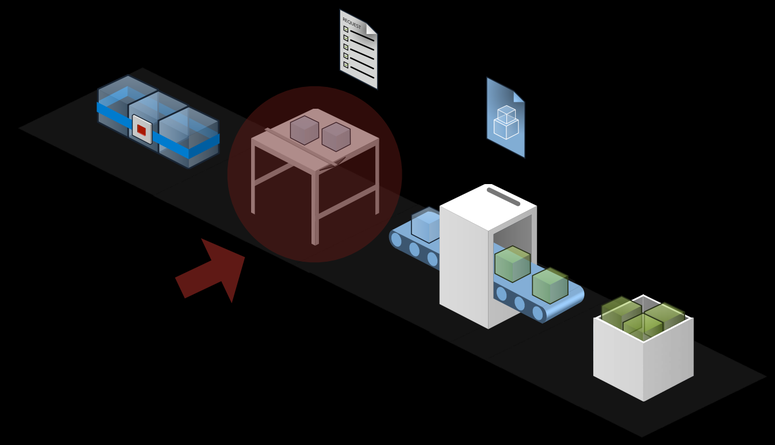
- Rollback (aka revert)
  - Returns to the last saved state
- Reset (clean slate entirely)
  - Invalidates all the objects with this context
  - Discard references to those objects and fetch them again
- Supports NSUndoManager
  - Undo
  - Redo

Undo and Redo



- Core Data uses NSUndoManager from Foundation
- Event loop based groupings
  - Changes coalesced each event loop
  - processPendingChanges
- Undo/redo across saves
- Disabling undo

Synchronizing Changes

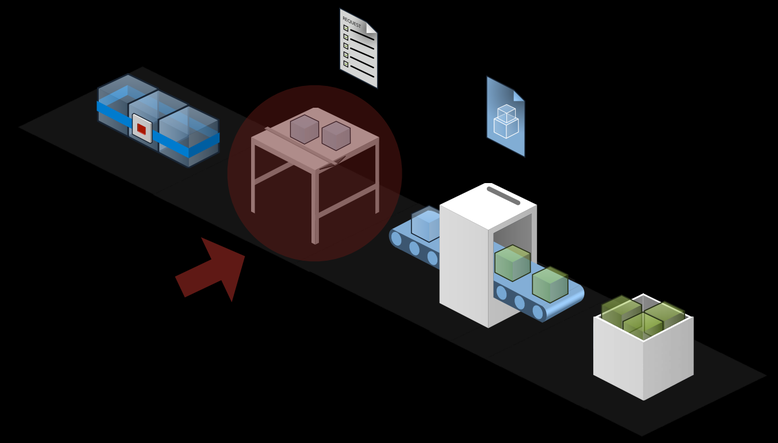


- Data freshness
  - Keeping objects up to date
  - Keeping similar objects in sync between different contexts or applications
- -refreshObject:mergeChanges:
- -setStalenessInterval:
- Alternatively, allow data to get stale
  - Handle conflicts with merge policies

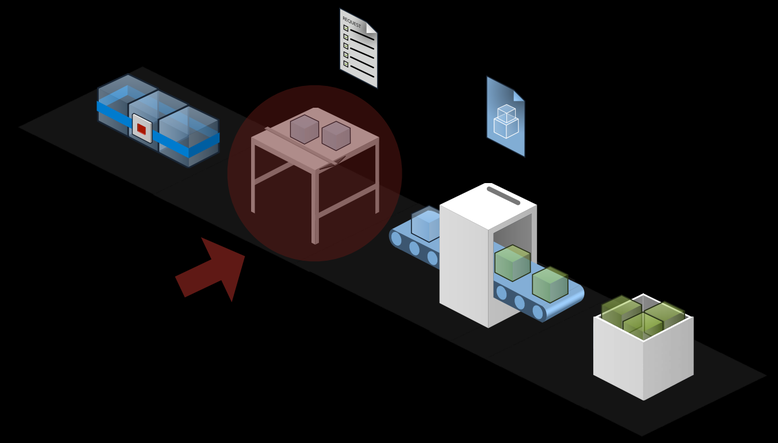
Merge Policies

Conflicting Writes

- Multiple writers
  - Multiple threads
  - One thread juggling multiple contexts
  - sqlite store and multiple applications

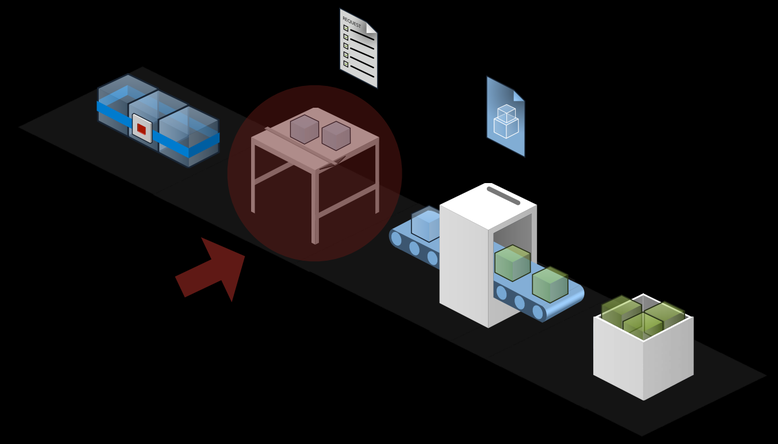


Detecting Conflicts



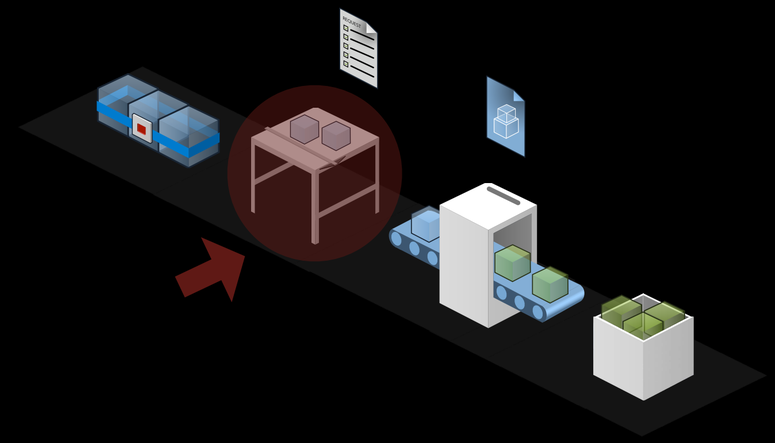
- Optimistic locking
  - Core Data assumes saves will succeed
  - Rolls back if a conflict occurs
- Only sqlite store handles conflicts on disk
  - XML and Binary stores perform atomic reads and writes

Merge Policies



- NSErrorMergePolicy
  - Default
  - userInfo has details for each conflict
- NSOverwriteMergePolicy
  - Last writer wins
- NSRollbackMergePolicy
  - First writer wins
- NSMergeByPropertyObjectTrumpMergePolicy
  - On property by property basis; last writer wins
- NSMergeByPropertyStoreTrumpMergePolicy
  - On property by property basis; first writer wins

Conflicts Involving Unchanged Data



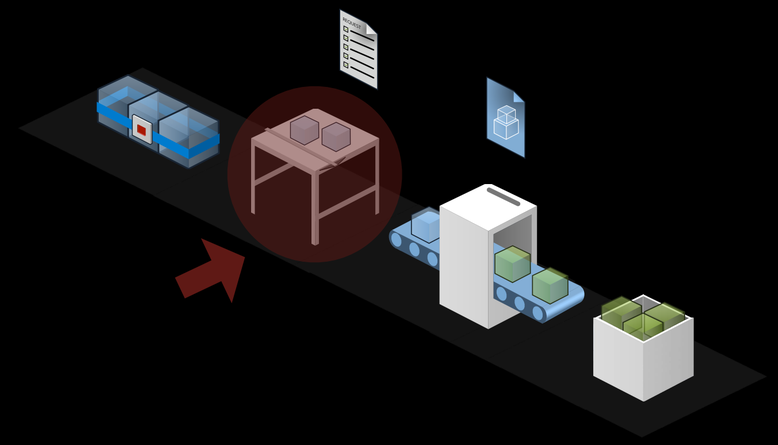
- Semantic conflicts
- -detectConflictsForObject:
  - RunningTotal = Cost1 + Cost2
  - Cost1 and Cost2 are properties on unchanged objects
  - Save new RunningTotal
    - But fail if Cost1 or Cost2 changed externally

Working With Multiple Contexts

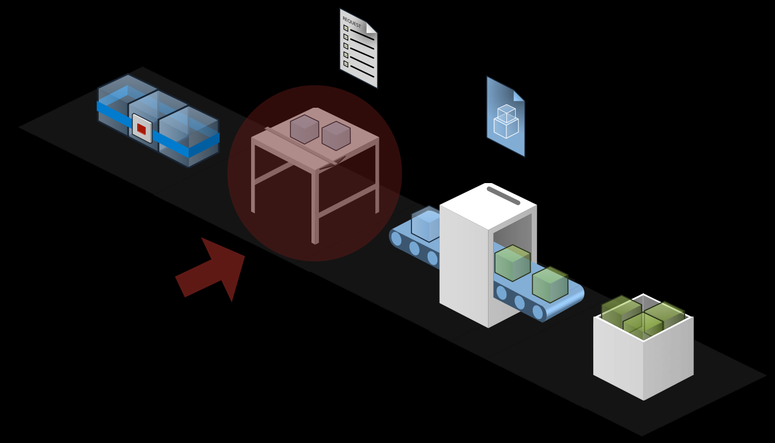
http://developer.apple.com/wwdc2005/

Why Do it?

- Isolate changes in different editors
- Save or undo different groups of changes independently
- Inspector windows
- Reduce working set in each context
- Work with multiple Persistent Store Coordinators

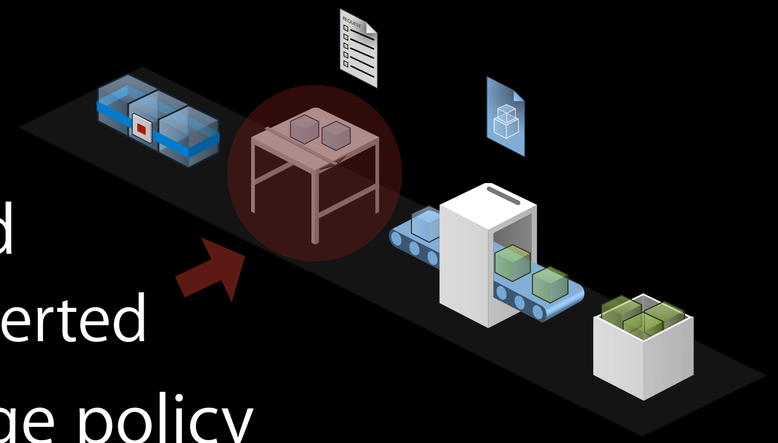


Things to Do

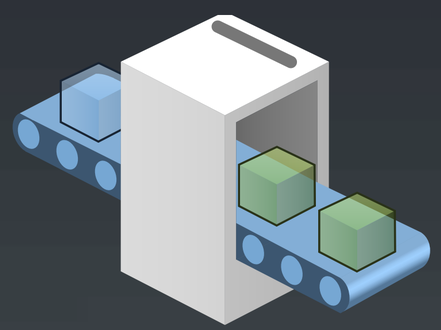


- Pass objectIDs around
  - Managed Objects can only be associated with one context
- If contexts are using the same coordinator
  - Load the manage object with objectWithID:
  - Or perform a fetch with a predicate
    - `[NSPredicate predicateWithFormat:@"self = %@", objectid]`
    - `[NSPredicate predicateWithFormat:@"self IN %@", arrayofids]`
- If contexts are using different coordinators
  - Persistent store must be added to both coordinators

Details



- Newly inserted objects are temporary until saved
  - Visible only in the context in which they were inserted
- Contexts changing the same data will need merge policy
- Sharing Persistent Store Coordinator shares caches
- Multiple Persistent Store Coordinator duplicates caches



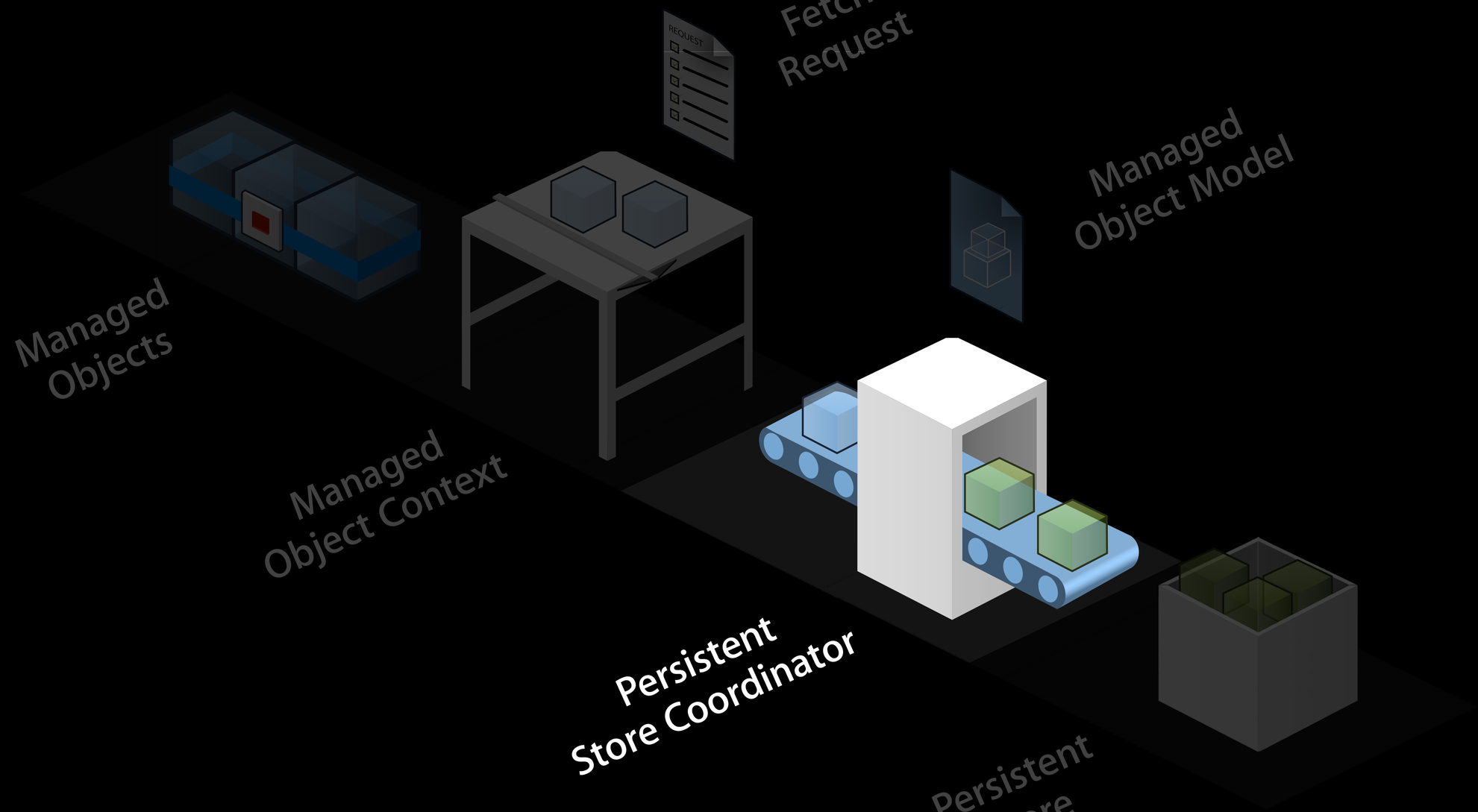
The Persistent Store Coordinator

And object stores

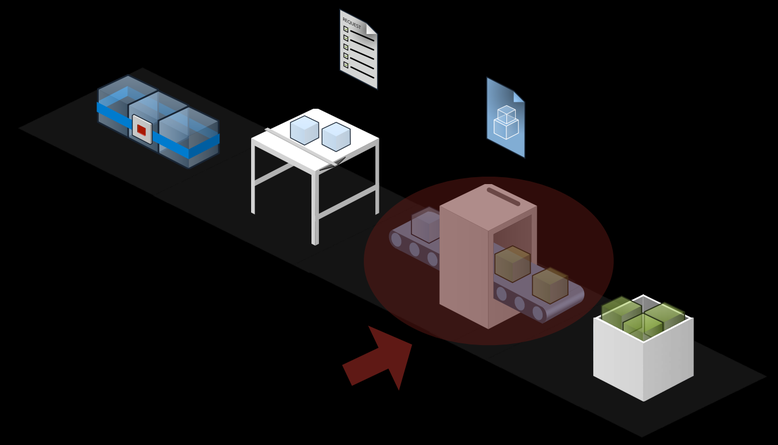
http://developer.apple.com/wwdc2005/

Core Data: Persistent Store Coordinator

NSPersistentStoreCoordinator

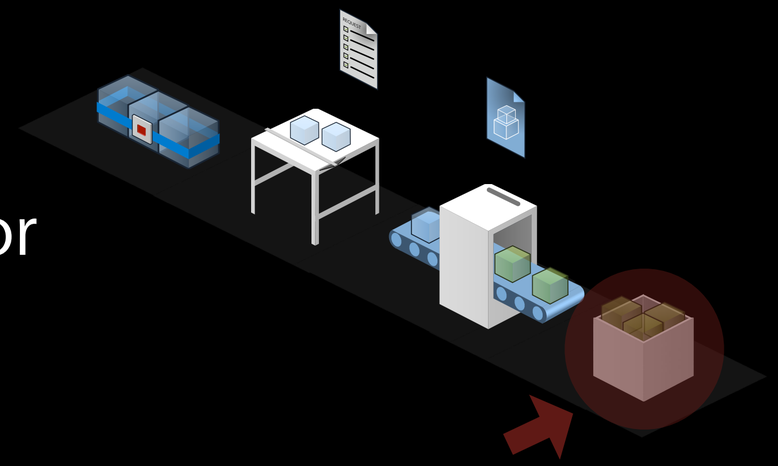


NSPersistentStoreCoordinator



- Bridge between object lifecycle management and persistence mechanisms
- Center of the framework's world
  - One persistent store coordinator per stack
  - Many contexts, many stores
- Provides a facade of a single store to the MOC
- Initialized with a managed object model

What, No NSObjectStore?



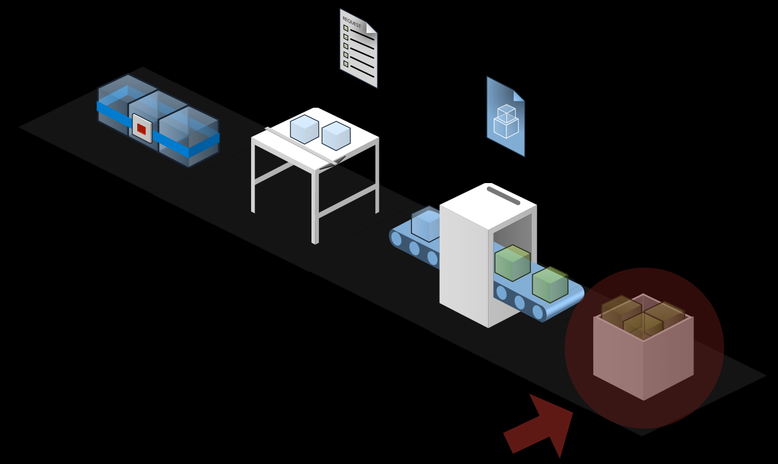
- Interaction through NSPersistentStoreCoordinator
- Stores created by type:
  - NSBinaryStoreType
  - NSXMLStoreType
  - NSSQLiteStoreType
  - NSInMemoryStoreType

Decision: Which Store Type?

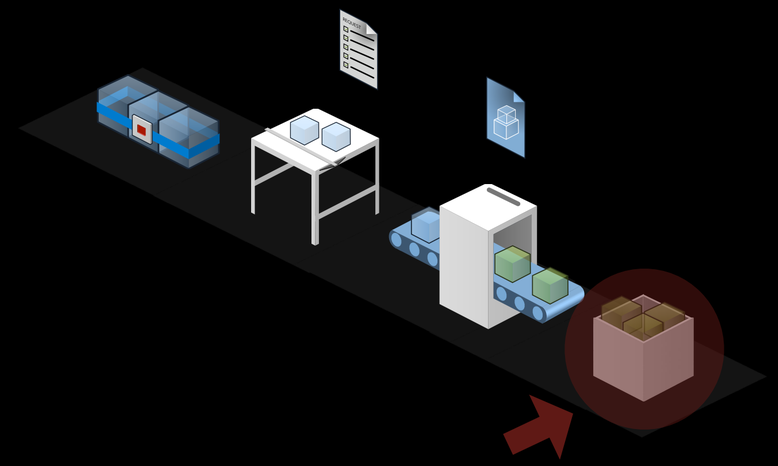
	XML	Binary	In Memory	SQLite
Speed	Slow	Fast	Fast	Fastest
Graph Size	Whole	Whole	Whole	Partial
Other	Externally parseable		No backing required	

In Memory Stores

- Just like any other store
- Doesn’t save to disk anywhere
- Useful for storing transient objects
  - singletons that are created every time

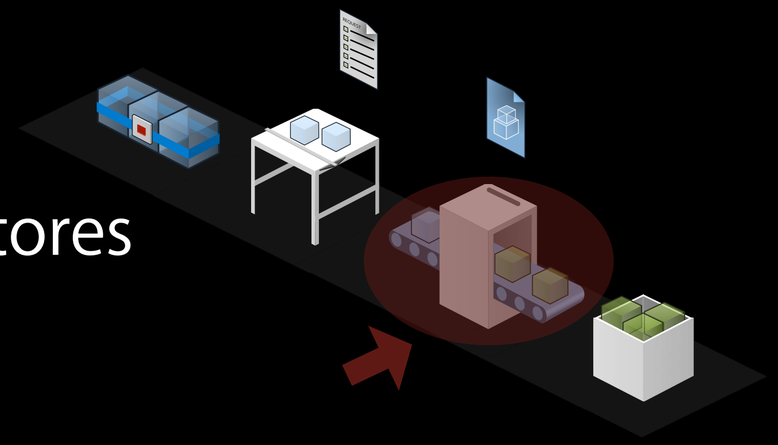


Problem: Legacy File Formats



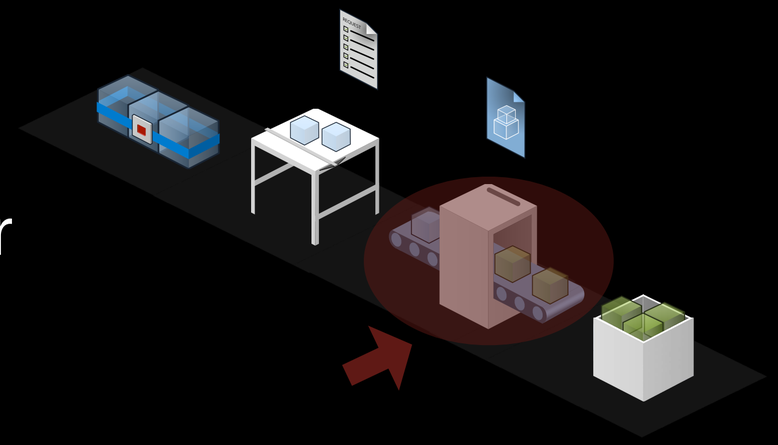
- Create your stack backed by an NSInMemoryStoreType
- Read your file and create your instances of NSManagedObject
- Use assignObject:toPersistentStore: to associate your objects with the in memory store
- Register for NSManagedObjectContextDidSaveNotification
- During objects associated with the store and manually save convert and save them

Working with Multiple Stores



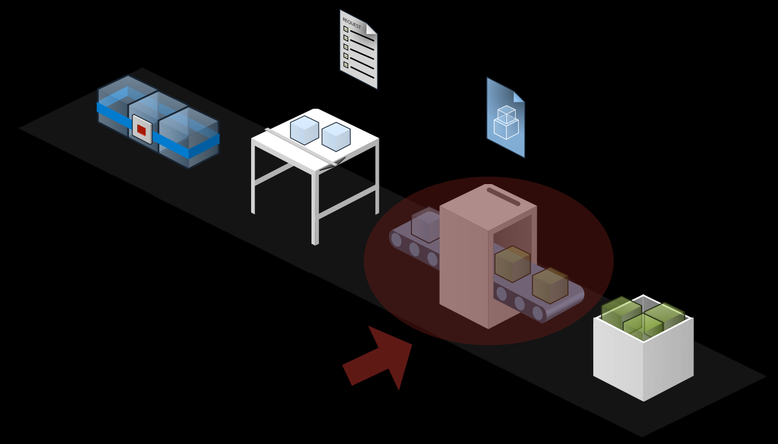
- By default, fetch requests retrieve data from all stores
- Use affectedStores accessors on fetch requests to direct requests to specific stores
- Objects are automatically assigned to stores at save time
  - Assignment can also be done using NSManagedObjectContext assignObject:toPersistentStore:
- Use configurations to relate entities to stores
- Considerations with Cocoa Bindings

Store Migration



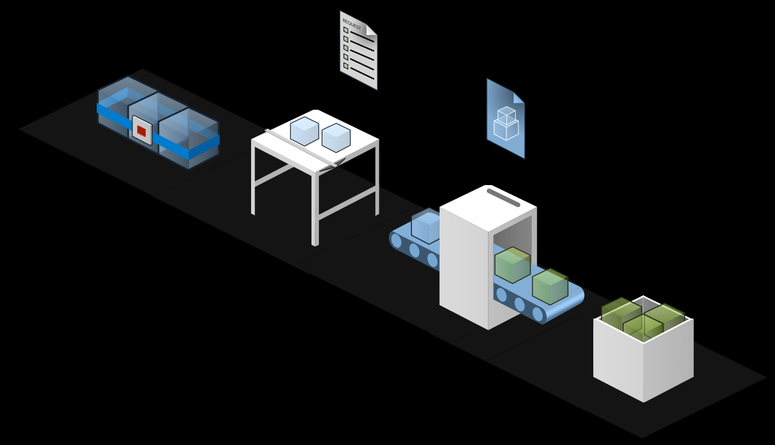
- Simple to move data from one format to another
- One call on NSPersistentStoreCoordinator
- Some caveats
  - Works by pulling everything in store into memory and resaving
  - Time and memory expensive
  - Old store will be removed
    - Managed Object Context will transition all its managed objects to new store
    - But objectIDs referencing the old store will be invalid

Store Migration

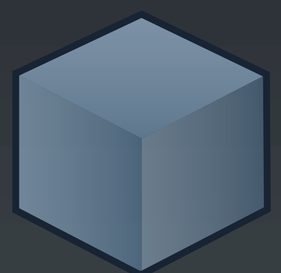


```
[coordinator migratePersistentStore: aStore toURL: aURL options: nil
withType: NSSQLiteStoreType error: &error];
```

Decision: NSPersistentDocument or Not



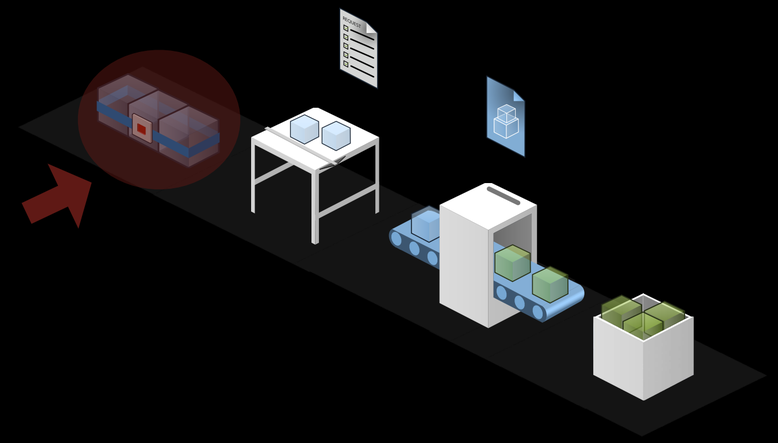
- Use NSPersistentDocument if
  - Data is contained in one store
  - Don’t have to worry about data from other sources
- Otherwise you want a non-document-based application



Cross-store Relationships

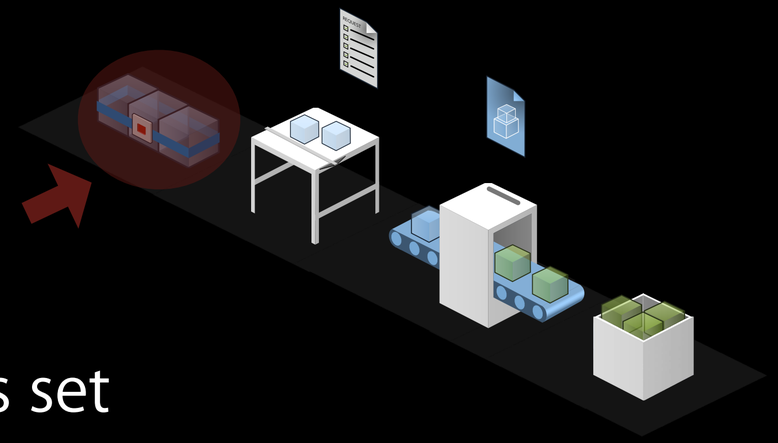
http://developer.apple.com/wwdc2005/

Creating Cross Store Relationships



- Not supported out of the box
- Can be implemented using
  - Transient properties
  - Fetched properties
- Requires a custom subclass of NSManagedObject

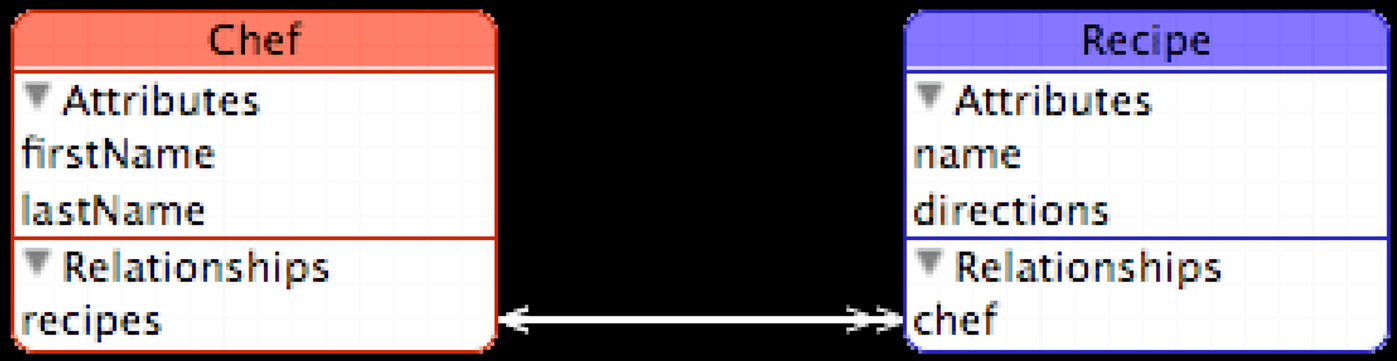
Two Patterns



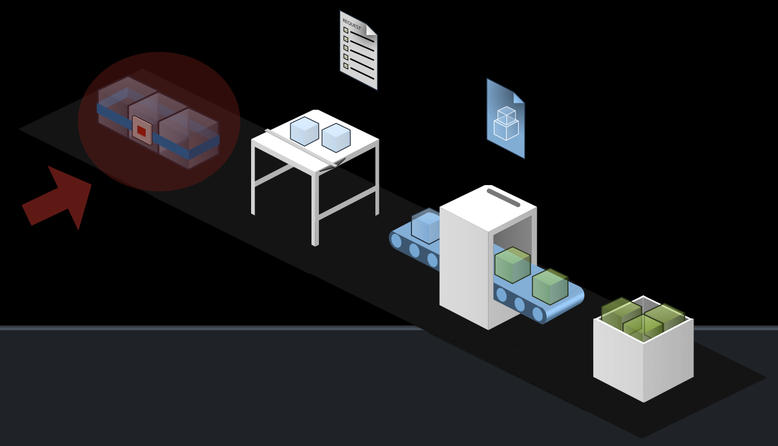
- Update storage at set time
  - Override custom accessor to push data to persistent backing attribute when new value is set
- Update storage at save time
  - Override -willSave to push data to persistent backing attribute
- Resolve relationships in awakeFromFetch

Cross Store Example

The Model



Code Example



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  [super willSave];
  [self willAccessValueForKey: @”chef”];
  NSManagedObjectID *moid = [[self primitiveValueForKey: @”chef”] managedObjectID];
  [self setPrimitiveValue: [moid URIRepresentation] forKey: @”chefid”];
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}
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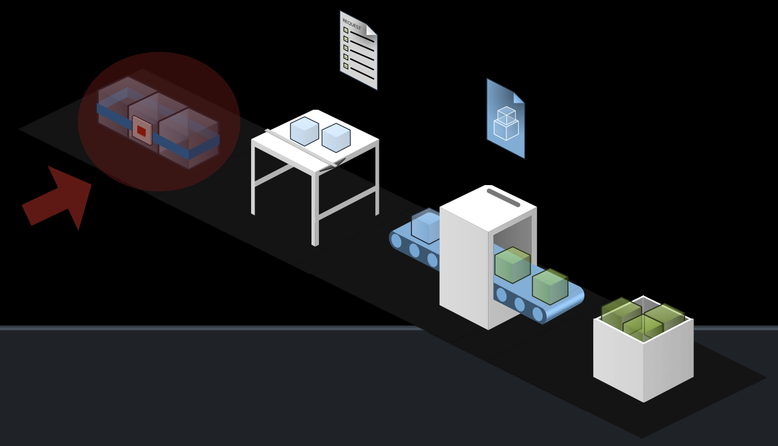

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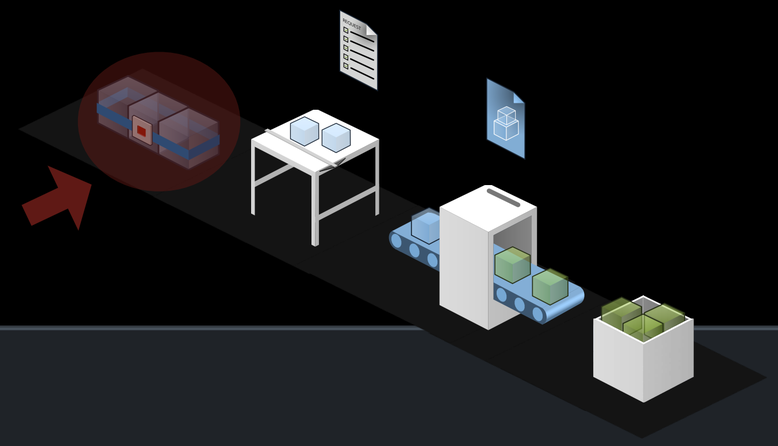

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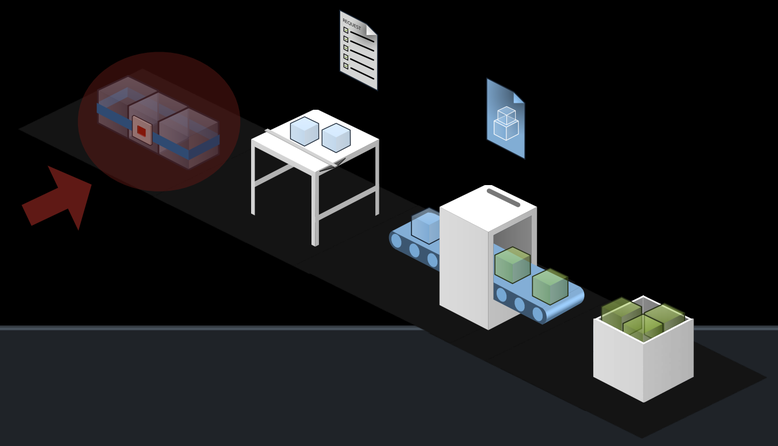

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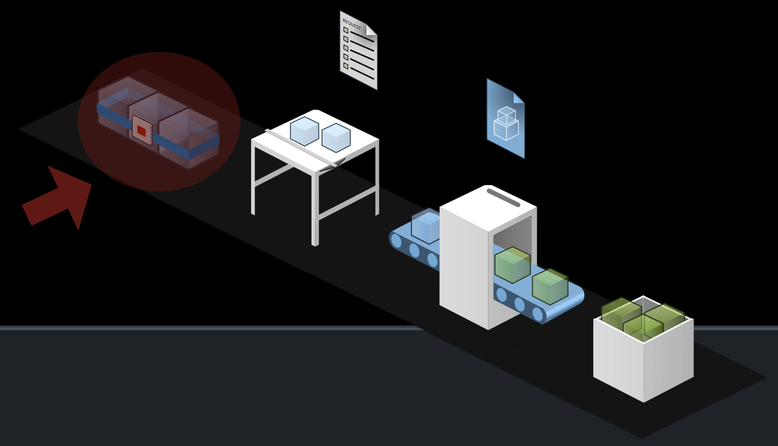

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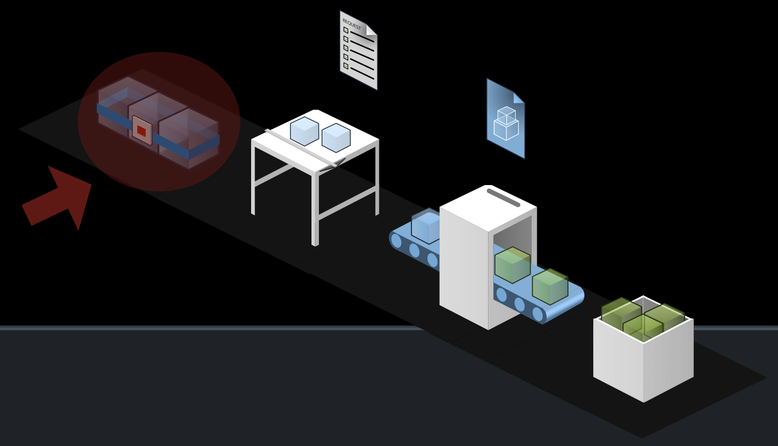

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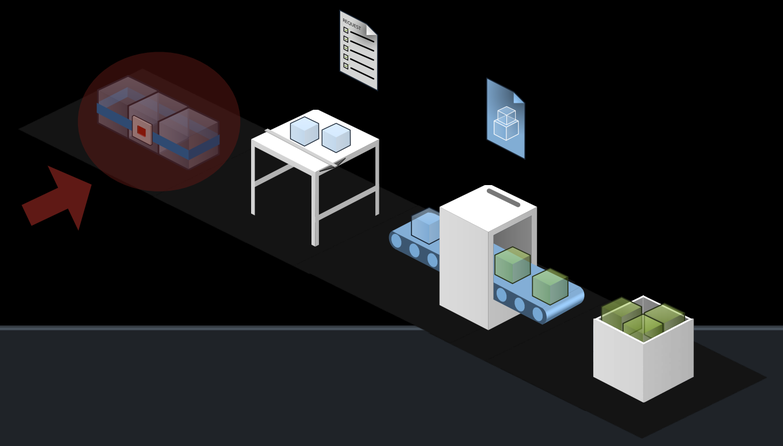

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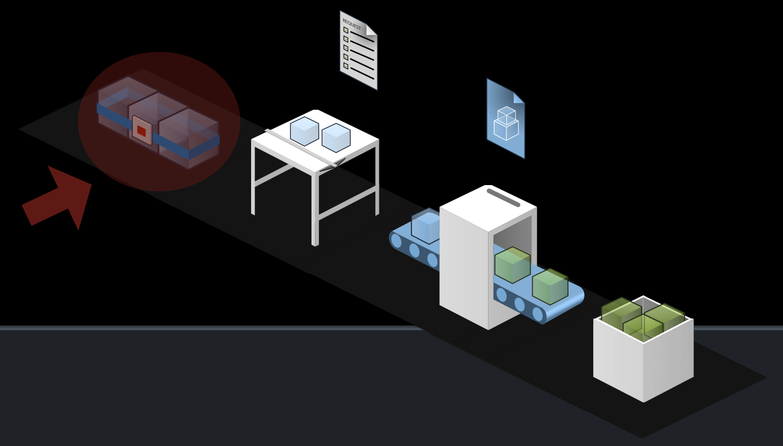

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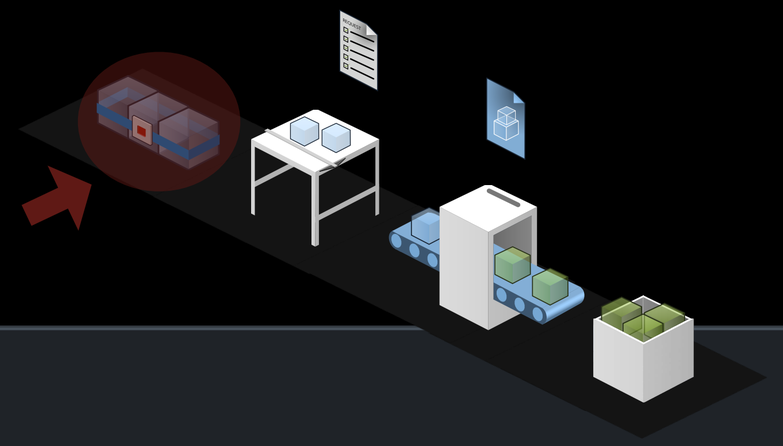

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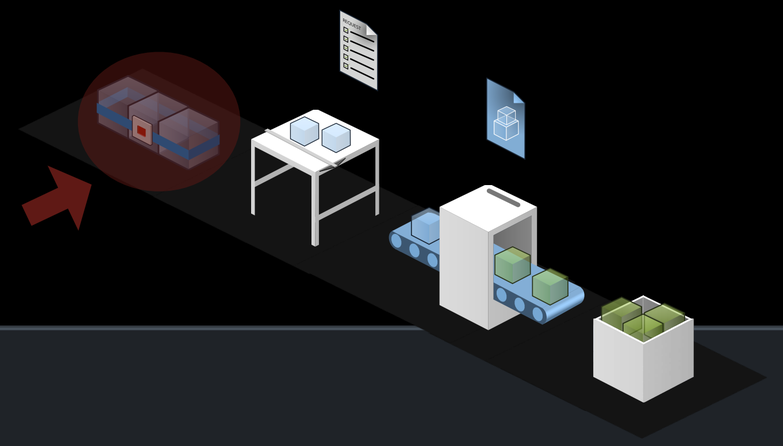

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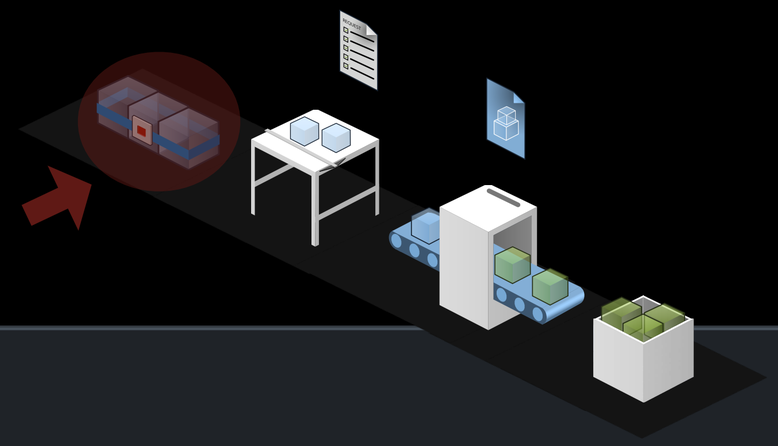

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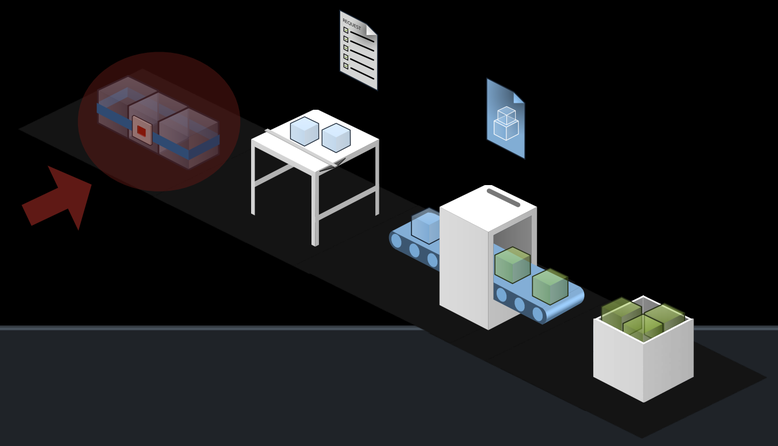

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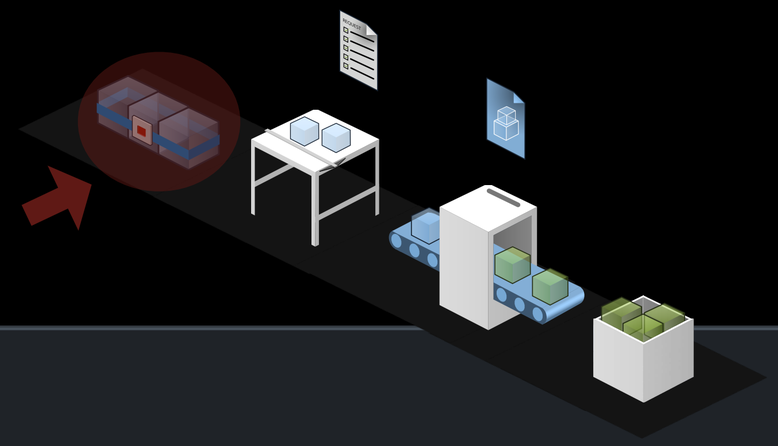

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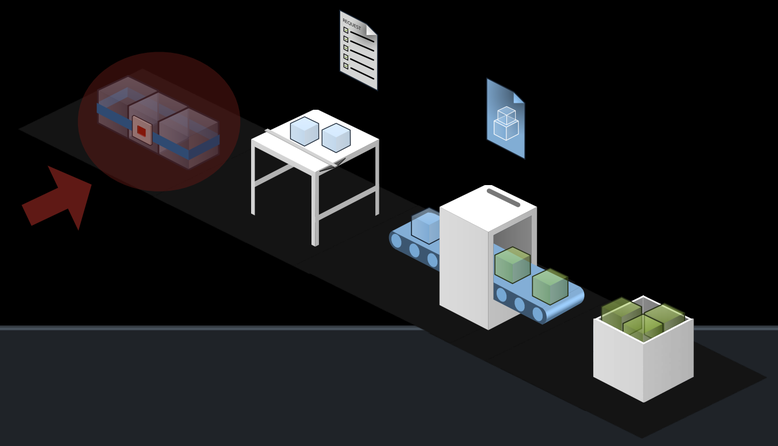
```

Code Example



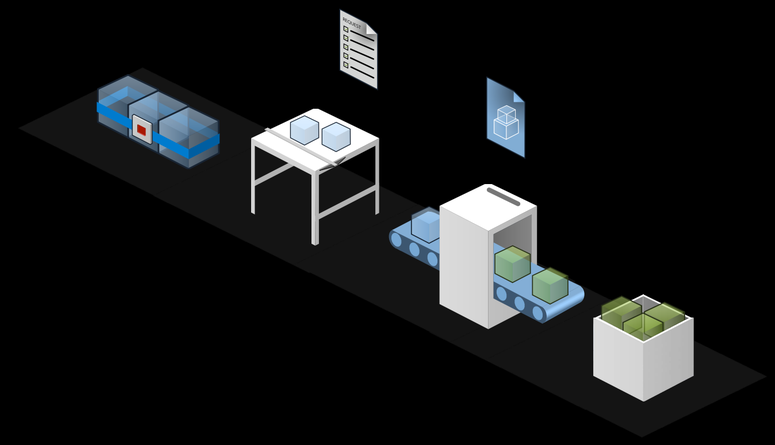
```
- (void)awakeFromFetch {
  [super awakeFromFetch];
  NSURL *chefiduri = [self primitiveValueForKey: @”chefid”];
  NSManagedObjectContext *context = [self managedObjectContext];
  NSPersistentStoreCoordinator *coordinator = [context persistentStoreCoordinator];
  NSManagedObjectID *moid = [coordinator managedObjectIDForURIRepresentation:
chefiduri];
  NSManagedObject *localChef = [context objectWithID: moid];
  [self setPrimitiveValue: localChef forKey: @”chef”];
}
```

Advanced Topics

http://developer.apple.com/wwdc2005/

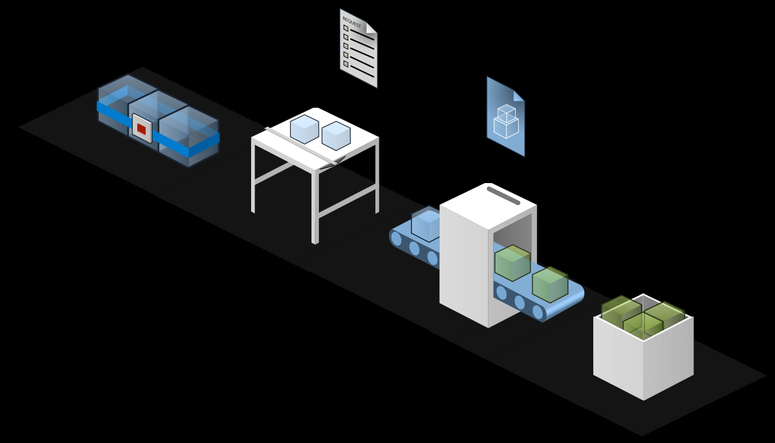
Spotlight Integration

Small Amounts of Metadata



- Put information you want exported into store metadata
- Use metadataForPersistentStoreWithURI:error: in Spotlight importer to extract data
- Duplicate data increases store size
- Recommended approach
  - Faster

Larger Amounts of Metadata

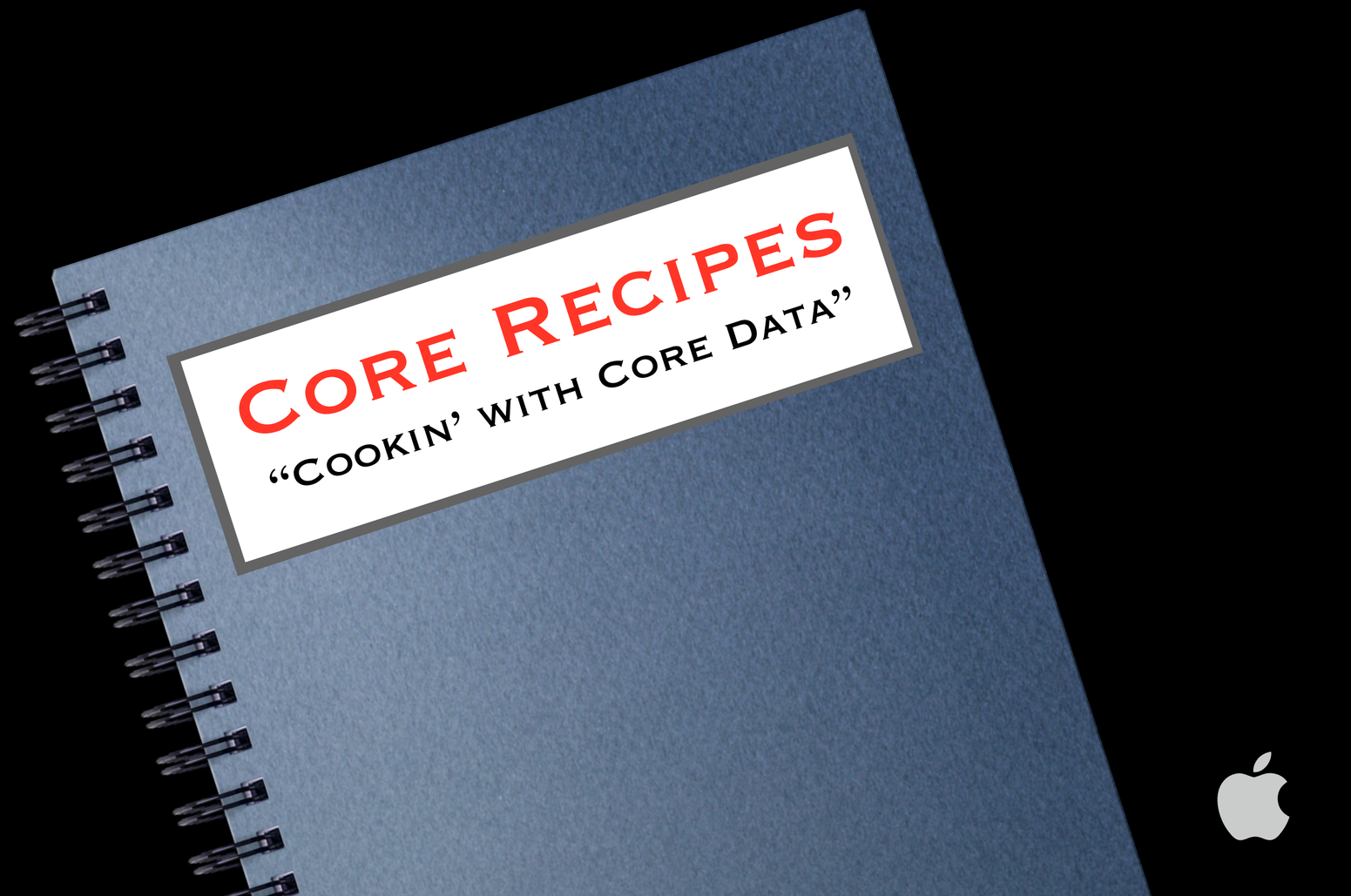


- Store information as you normally would
- Create a persistent stack in Spotlight importer
- Use fetch requests to retrieve desired data
- Persistent stacks are heavyweight
- Slower, but no duplication

WWDC Sample Code

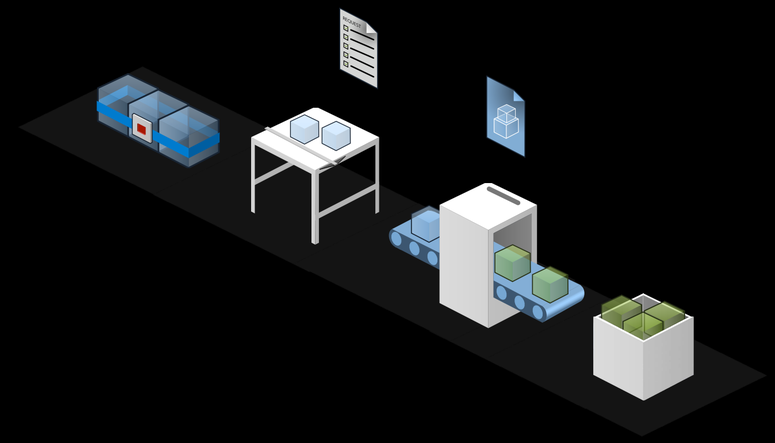
“CoreRecipes”

- CoreRecipes application
  - Spotlight integration



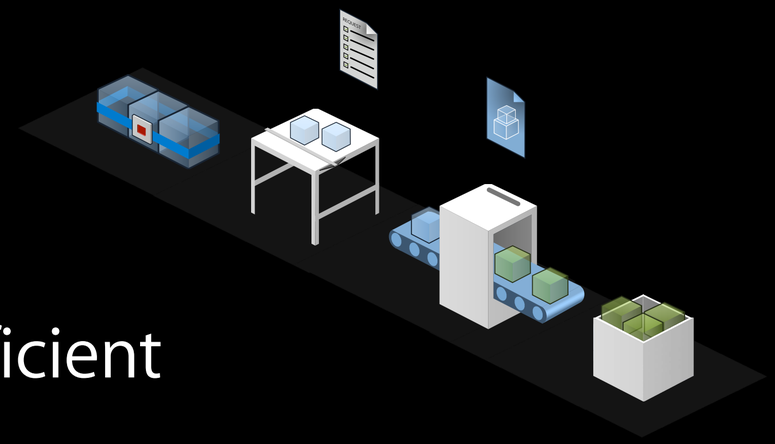
Memory Management

Memory Management



- Weak references between MOs and MOC
- Managed Objects can act as proxies
- Faulting is similar to virtual memory paging
- Core Data Programming Guide
  - Section “Using Managed Objects”

Problem: How to Handle Large Datasets

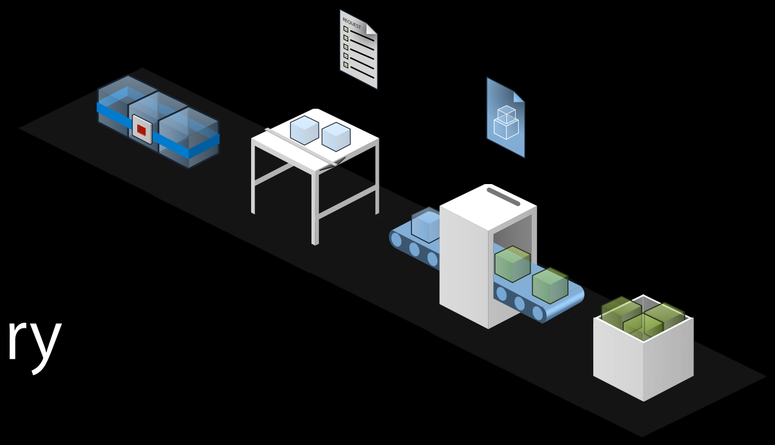


- Opening atomic stores is slow and memory inefficient
  - Use SQLite store if possible
  - Binary is the second best option
- Minimize working set
  - Only retain objects you need
  - Let others be turned back into faults and/or released

Threads

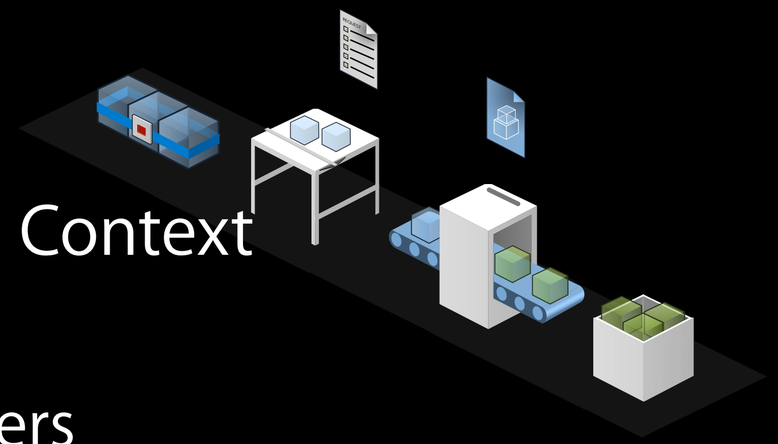
http://developer.apple.com/wwdc2005/

Threading Basics



- CoreData classes not implicitly thread safe
- NSManagedObject similar to NSMutableDictionary
- CoreData framework locks objects it uses
  - Context locks Coordinator internally during fetch, save, etc
- You must lock (or not share) objects you use
  - Generally “use” means:
    - send messages to an object
    - access an object’s ivars

Threading Tips



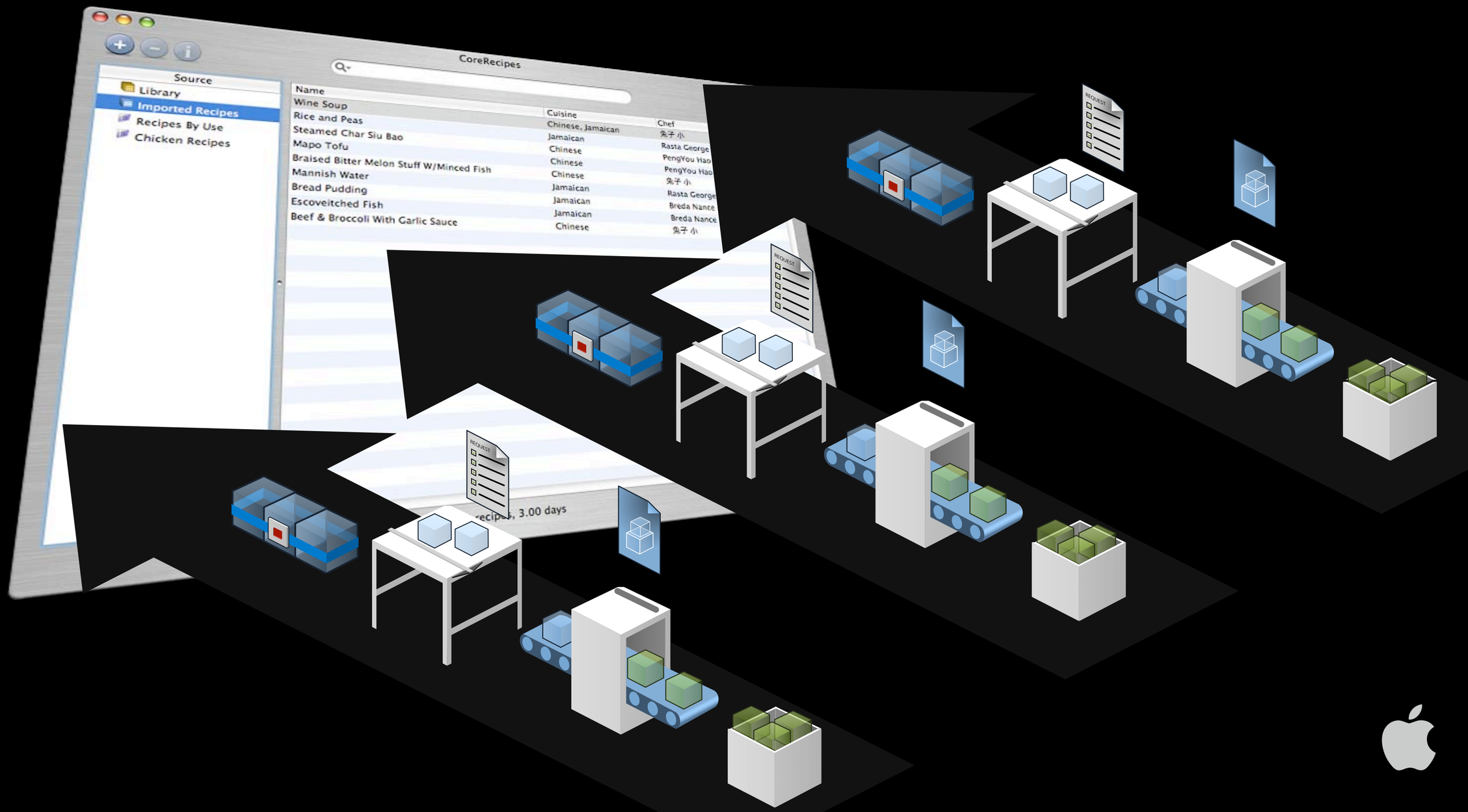
- Each thread has its own private Managed Object Context
- Only pass managed object IDs!
  - Okay to pass objectIDs between threads as pointers
  - Unnecessary to use URIRepresentation
- Do not pass managed objects or contexts between threads

One Context per Thread

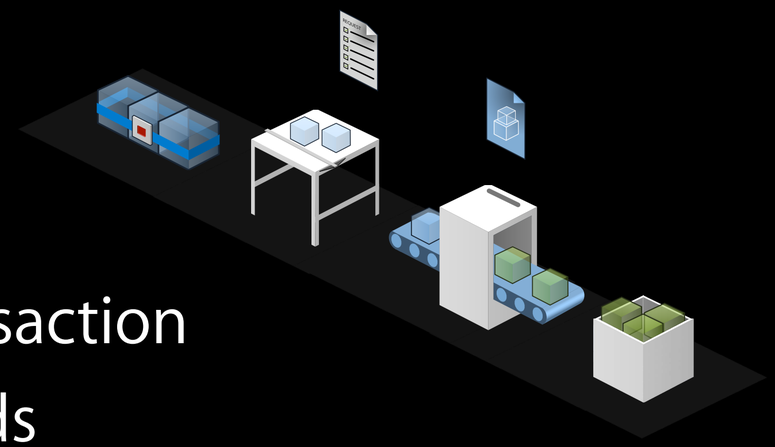
Shared Persistent Store Coordinator

One Stack per Thread

More concurrency, but no shared caches

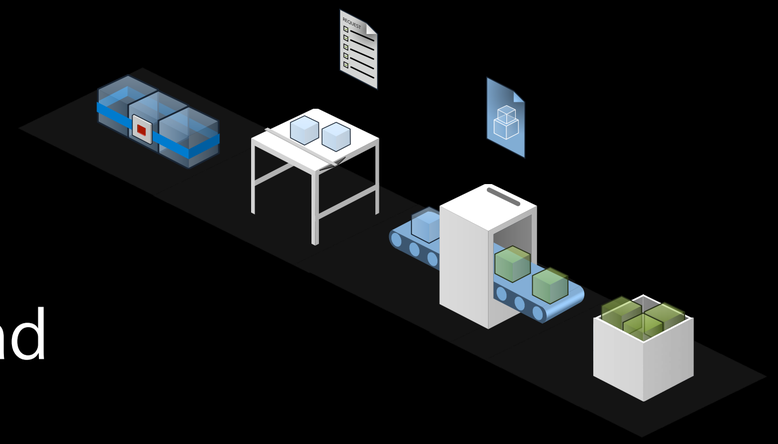


Locking



- Not just thread safety
  - Locking signals to framework the scope of a transaction
  - Prevents interspersing of edits by different threads
  - Save changes coherently
  - Keep operations distinct on the undo stack
- Therefore
  - Thread must own Context to access any Managed Object registered with that Context
  - Locking around a Managed Object setter insufficient
    - Lock the Context instead

Cocoa Bindings & AppKit

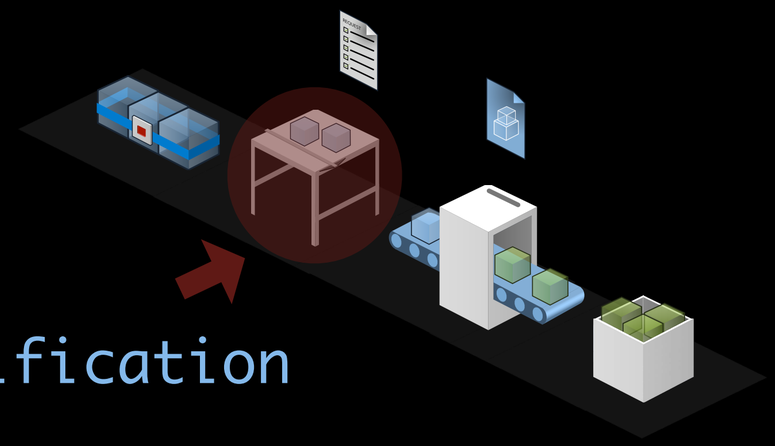


- Completely totally NOT thread safe
- All work with Controllers MUST be on main thread
- Use -performSelectorOnMainThread:

Core Data Notifications

http://developer.apple.com/wwdc2005/

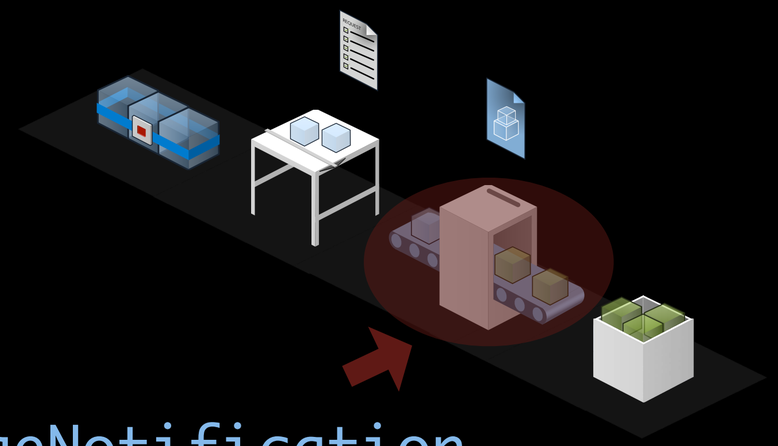
MOC Notifications



- `NSManagedObjectContextObjectsDidChangeNotification`
- `NSManagedObjectContextDidSaveNotification`

- Notification userInfo dictionary has
  - Inserted, updated, deleted keys
  - NSSets of managed objects

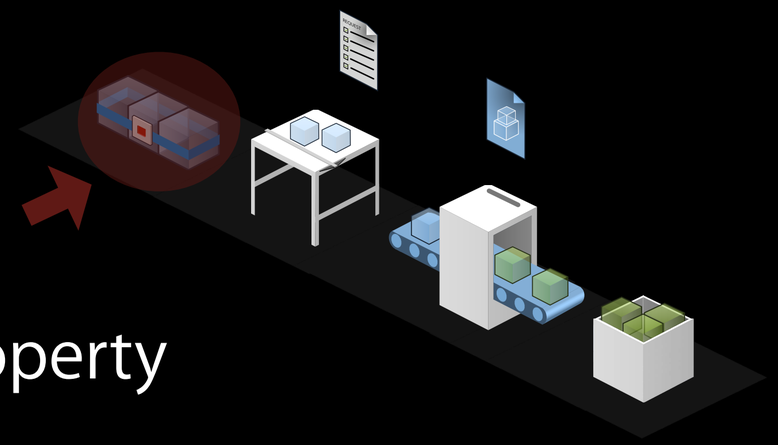
PersistentStoreCoordinator Notifications



- `NSPersistentStoreCoordinatorStoresDidChangeNotification`

- Notification userInfo dictionary has
  - Added, removed, UUID changed keys
  - NSArrays of persistent stores references

KeyValueObserving Notifications



- Managed Objects send KVO notifications per property
  - will/did access for valueForKey: or public getters
  - will/did change for setValue:forKey: or public setters
  - Undo and redo operations
  - Relationship maintenance (inverses, delete propagation)
- Primitive KVC operations do NOT send KVO notifications

Common Errors

http://developer.apple.com/wwdc2005/

Developer Errors

- Changing a model and accessing previously saved data
- Forgetting to send KVO notifications in custom accessors
  - Accessing ivars directly
  - Misusing primitiveValueForKey: & setPrimitiveValueForKey:
- Not letting the framework drive
  - Retaining objects you don’t need
  - Implementing accessors you don’t need
  - Micromanaging

Common Error Messages

```
NSError with reason @”Could not merge changes.”
```

- Two writes conflicted (different contexts tried to change the same data) aka optimistic locking failure
- Set a merge policy on the context, or
- Manually resolve the failure

Common Error Messages

```
NSError with reason @”Core Data could not
fulfill a fault.”
```

- The object’s underlying data has been deleted from the object store
- You should discard this object

Common Exceptions

```
*** Uncaught exception:
<NSUnknownKeyException> [<MyMO 0x3036b0>
valueForUndefinedKey:]: this class is not key
value coding-compliant for the key randomKey.
```

- You have a typo in the key, or
- You initialized your managed object with -init instead of initWithEntity:inManagedObjectContext:

Common Exceptions

```
*** Uncaught exception:
<NSInvalidArgumentException> [<MyMO
0x3036b0>_assignObject:toPersistentStore:]: Can’t
assign an object to a store that does not contain
the object’s entity.
```

- You are trying to assign an object to a store that can’t hold it
- Assign object to a store which contains instances of the objects’ entity

Common Exceptions

```
*** Uncaught exception:
<NSInvalidArgumentException> [<MyMO
0x3036b0>_assignObject:toPersistentStore:]: Can’t
reassign an object to a different store once it has
been saved.
```

- The object you are trying to assign has already been assigned and saved
- To move it, you must create a new instance, copy the information from the old object, and delete the old instance

Common Exceptions

```
*** Uncaught exception:
<NSObjectInaccessibleException> [<MyMO
0x3036b0>_assignObject:toPersistentStore:]: The
NSManagedObject with ID:#### has been invalidated.
```

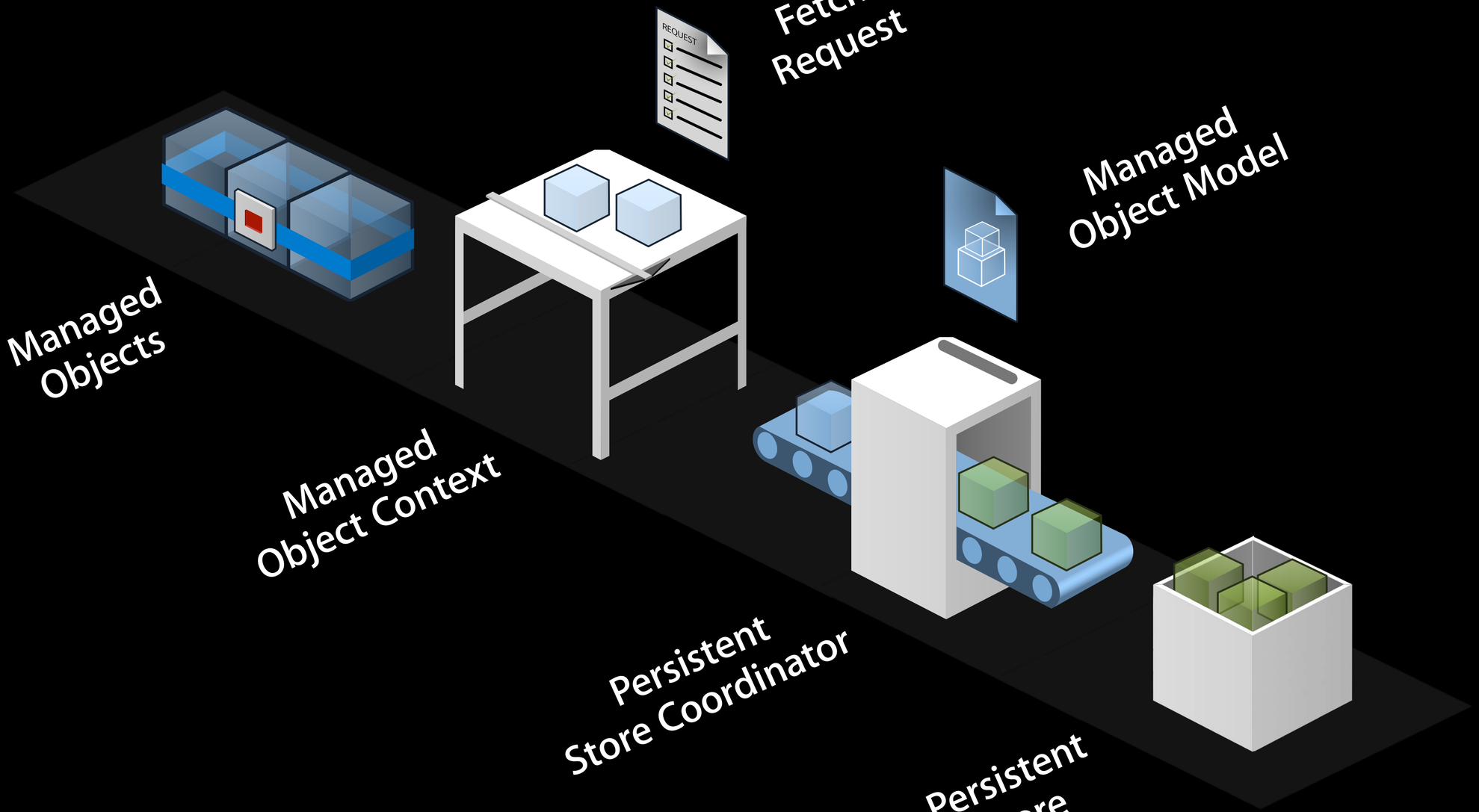
- The store for the fault you are attempting to fire has been removed, or
- The context has been -reset
- You should toss the object
- If you wish to re-add the store, fetch it again

Summary

http://developer.apple.com/wwdc2005/

Core Data

Object management and persistence



Summary

- Core Data architecture
- Roles of components in a Core Data stack
- Decision points when writing a Core Data application
- Patterns to use when confronted with complex problems
- Common errors and exceptions in Core Data applications

More Information

http://developer.apple.com/wwdc2005/

Documentation, Sample Code, and Other Resources

http://developer.apple.com/wwdc2005/

Already at Your Fingertips…

Lots of information and samples

Documentation

- Core Data Programming Guide
- NSPersistentDocument Core Data Tutorial
- Low-Level Core Data Tutorial
- Core Data Objective-C Reference (and update)

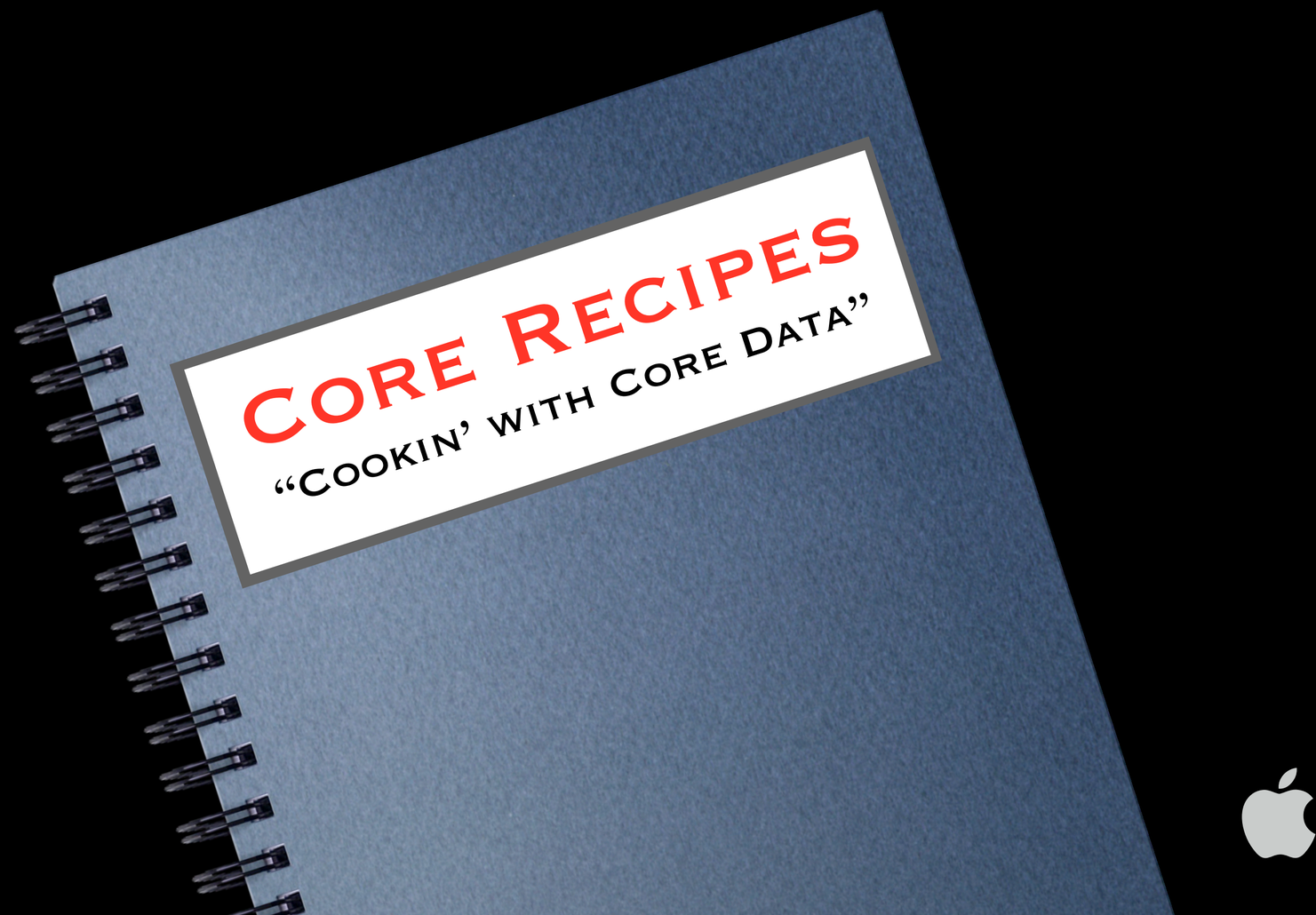
/Developer/Examples/CoreData

- OutlineEdit
- Stickies
- Tile Puzzle
- Event Manager

WWDC Sample Code

“CoreRecipes”

- Hands-on samples (for tomorrow’s session)
  - Command-line and GUI application
- CoreRecipes application
  - Core Data essentials
  - Cocoa bindings
  - Spotlight integration
  - Automator action
- Data migration sample



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Q&A

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